PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSIONS ~~NINETEEN~~ TO TWENTY-FIVE.

1878–1884.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

VOL. IV.

LIVERPOOL:

C. TINLING & CO., PRINTERS, VICTORIA STREET.

1885.

TABLE OF CONTENTS,

VOL. IV.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTIETH.

1878-9.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

PART I.—VOL. IV.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1879.

OFFICERS, 1878-9.

President.

WILLIAM SEMMONS.

Vice-President.

J. CAMPBELL BROWN, D.Sc., F.C.S.

Ex-President.

HUGH F. HALL, F.G.S.

Honorary Treasurer.

ALFRED MORGAN.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

R. A. ESKRIGGE, F.G.S.

ISAAC ROBERTS, F.G.S.

FREDERICK P. MARRAT.

CHARLES RICKETTS, M.D., F.G.S.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTIETH.

OCTOBER 8TH, 1878.

THE VICE-PRESIDENT, WILLIAM SEMMONS, in the Chair.

GRANVILLE OLDFIELD JACKSON was elected an Ordinary Member of the Society.

The Anniversary Address was read by the Vice-President.

NOVEMBER 12TH, 1878.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

W. H. ADDISON, JOHN JAMES WOOD, WILLIAM H. QUILLIAM, and THOMAS STONE were elected Ordinary Members of the Society.

The following communications were read:—

ON SOME PSEUDOMORPHS OF CHRYSOCOLLA AFTER ATACAMITE.

By William Semmons.

GEOLOGICAL RESULTS OF THE BRITISH ARCTIC EXPEDITION UNDER CAPTAIN SIR G. NARES, R.N.

By C. E. de Rance, F.G.S., Assoc. Inst. C.E., and of H.M. Geological Survey.

ON SOME REMARKABLE PEBBLES IN THE BOULDER-CLAY.

By Charles Ricketts, M.D., F.G.S.

DECEMBER 10th, 1878.

The President, WILLIAM SEMMONS, in the Chair.

The following communication was read:—

FURTHER OBSERVATIONS ON THE CEFN-Y-FEDW SANDSTONE AND CARBONIFEROUS LIMESTONE OF THE COUNTRY SOUTH OF LLANGOLLEN. (Printed in Vol. III.)

By George H. Morton, F.G.S.

JANUARY 14TH, 1879.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

The following communications were read:—

A REVIEW OF DR. F. V. HAYDEN'S GEOLOGICAL AND TOPOGRAPHICAL ATLAS OF COLORADO, WITH A SKETCH OF THE GEOLOGY OF NORTH WESTERN AMERICA.

BY ALFRED MORGAN.

ON SOME GLACIAL STRIÆ ON THE NORTH WALES COAST.

BY AUBREY STRAHAN, M.A., F.G.S.
H.M. GEOLOGICAL SURVEY.
By permission of the Director-General of the Geological Survey.

FEBRUARY 11TH, 1879.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

The following communications were read:—

RECENT AND FOSSIL NASSA.

BY F. P. MARRAT.

ON THE INTERGLACIAL AGE OF THE CAVE-MAMMALIA;

The apparently Sudden Introduction of Man; the Mental Capacity of the Cave-Men of France; and the Shortness of the Time which has elapsed since the Close of the last Glacial Period.

BY DANIEL MACKINTOSH, F.G.S.

MARCH 11TH, 1879.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

DANIEL MACKINTOSH, F.G.S., was elected an Ordinary Member of the Society.

The following communications were read:—

ANALYSES OF ROCKS FROM THE 1,300 FEET BORE-HOLE AT BOOTLE.

BY J. CAMPBELL BROWN, D.Sc., F.C.S.

NOTES ON THE SCENERY AND GEOLOGY OF IRELAND.

BY T. MELLARD READE, C.E., F.G.S.

ON SOME PSEUDOMORPHS OF CHRYSOCOLLA AFTER ATACAMITE.

By W. Semmons.

The crystalline forms assumed by various minerals, by their regularity of shape and beauty of colour, attract the attention of even most casual observers.

"Flowers of the stony world," they are frequently and truly called.

The marvellous play of forces during their formation is graphically and enthusiastically portrayed by Prof. Tyndall, in his "Forms of Water."

The occurrence of crystals in our metallic veins at the greatest depths yet reached, shows the same forces have been and are at work in the filling up of these repositories of our mineral wealth.

Pseudomorphic crystals possess further features of interest, particularly those of the Metasomatic class.

Hypostatic pseudomorphs are of interest as showing the relative ages of deposits; but Metasomatic still more so, as showing not only this fact, but also the changes which, taking place on a large scale, give rise to our Gossans and Kaolins. From pseudomorphs are confirmed the conclusions drawn from other sources as to the derivation of the immense masses of Brown Iron Ore which cap the deposits of Cupreous pyrites in Spain and Portugal, and which on a smaller scale are to be seen in the Gossans on the backs of lodes in Cornwall and elsewhere.

The Metasomatic pseudomorphs which I have the honour of laying before you this evening—viz., of Chrysocolla after Atacamite, are, I believe, now noticed for the first time.

From correspondence with which I have been favoured by Prof. Ruddler, F.G.S., Mr. Thos. Davies, F.G.S., of the British Museum, and others, I find that Chrysocolla, though evidently derived often from the decomposition of other ores of Copper, has only been noticed as yet pseudomorphic after Malachite, Chalcophyllite, Cuprite, Libethenite (ores of Copper), Galena and Cerussite (ores of Lead), and Barytes.

In my examination of some Chilian ores I was, whilst looking for crystals of Dioptase, much struck with the occurrence of a mass of small crystals which possessed the peculiar lustre of Chrysocolla. On a close examination I found many of the crystals were broken, and these revealed the fact that the interior portion in some cases consisted of the chloride (Atacamite). Testing with the blow-pipe, I found the external portions of these partially decomposed crystals to be quite infusible, and characteristic of Chrysocolla, while the interior gave the beautiful blue flame characteristic of Atacamite. The further test of solution in hydrochloric acid showed the presence of gelatinous Silica. In this stone the crystals are the ordinary form of Atacamite.

No. 2 shows a mass of interlacing crystals, many of which are only partially, but some wholly converted into Chrysocolla. The proof of their origin can be clearly traced, as the main mass of the amorphous portion still remains as unaltered Atacamite.

No. 3, from another locality, is a stone of the greatest interest. The Atacamite has almost wholly disappeared.

Where it remains it is as a fine powder in the centre of the crystal. One crystal accidentally broken across shows a central cavity similar to those found in the interesting pseudomorphs of Galena after Pyromorphite.

In my paper on the Chrysocolla group (Proc. L'pool Geological Society, 1877–8), I showed that the order of deposition in the Chili deposits seemed to be Chloride, Carbonate, and Silicate; and some stones I afterwards found confirmed this, as we have crystals of Malachite set up in a matrix of Chloride. These have been afterwards coated by Silicate, and sometimes probably converted into it. The close connection of volcanic energy with carbonated and silicated waters naturally leads to the supposition that this ore has been first deposited as a Chloride (a well-known volcanic product) and has afterwards been acted on by such waters. The occurrence of pebbles, too, much water-worn, in one of the veins, lends further evidence to the fact of water action being at one time active. These pebbles I only discovered very lately, and I have not yet ascertained their chemical composition. In the paper above referred to I noticed the very remarkable fact that whilst in company with my friend Mr. W. M. Hutchings, of the Freiburg School of Mines, I had examined thousands of tons of Chrysocolla from the Mexican mines, we had failed to detect a single crystal of the Silicate of Copper. Shortly after this we found, on examining some from Chili, several small crystals of Dioptase, and these were described by Dr. Burghardt before the Manchester Literary and Philosophical Society. It seems, however, from information kindly furnished me by Mr. Thomas Davies, F.G.S., of the British Museum, that the National collection already contained several specimens of Chili Dioptase.

The interesting pseudomorph which forms the subject of this communication has, up to the present, no representative in our noble National collection; but it is rather on account of the knowledge it gives us of some of the forces at work below the surface of the Globe, that I bring it forward to the notice of Geologists.

ON SOME REMARKABLE PEBBLES IN THE BOULDER-CLAY.

By Charles Ricketts, M.D., F.G.S.

Erratic pebbles, ice-marked and otherwise eroded, occur so abundantly in the Boulder-clay of Cheshire and Lancashire, that they can never have escaped observation. There are others not so exceedingly infrequent which, with evidences of similar erosion, bear also indications of weathering, but in such peculiar forms that it must have occurred under circumstances very different from what prevails at the present time in any locality from which these pebbles could, by any possibility, have been originally derived.

Large blocks of Granite and Trap (Figs. 1 and 2), and also of sandstone are occasionally met with, having their surfaces entirely free from ice-marks, and are weathered all over, excepting at a neck-like portion, where they have been broken off as at a joint. In such examples the disintegration may have occurred whilst in their original position. Such appears certainly to have been the circumstances under which the sculpturing has occurred in an example of Silurian Grit; the strata standing out in relief, or forming hollows, according as

the material is harder or softer in texture; whilst the under surface has been simply separated along the bed. It appears as if this remarkable specimen had formed the summit of a pinnacle of rock (Fig. 3). In many examples of different varieties of rock, where old joints have been cemented together by a harder material, such as quartz, these stand out in bold relief; erosion not having occurred in them to an extent equal to that of the more easily disintegrated matrix.

Blocks of Granite, of various kinds, and derived from different localities, are abundant in the Boulder-clay. The surfaces of some are weathered and rough, whilst others are smooth and polished; many of them are more or less disintegrated, not unfrequently to such an extent that, though when *in situ* each granule remains in its relative position as when first formed, the mass cannot be handled without immediately falling into pieces; even with many of these blocks a careful examination indicates that they have been previously subjected to ice-polishing. A similar condition is also frequent with many volcanic rocks. In some the rock is rotten throughout, and peels off in layers; where this occurs, but has not progressed to so great an extent, the centre remains unaffected, forming a mass of a more or less globular form. The existence of these disintegrated boulders have been noticed by others, but no attempt has been made to determine the causes of their peculiar condition. In other Trap boulders having a different character the whole surface has been roughened and honeycombed; sometimes portions have escaped this erosion and project beyond the weathered surface; or grooves or hollows have been formed in the block. The projections when flat or smooth, especially if also covered with striæ, prove a previous exposure to glacier-action. In Porphyries the more

indestructible crystalline materials also protrude beyond the eroded surface. It is of constant occurrence and common to a variety of different conditions of weathering in rocks of volcanic origin, that, when found *in situ* in the Boulder-clay, or shortly after being thrown out by the workmen, they are covered, and the hollows filled, with a light green powder combined with other minute fragments of the disintegrated mass. These particles adhere so little amongst themselves, that the first heavy shower washes all away.

A very large proportion, amounting probably to nearly a third of the Carboniferous Limestone pebbles, bear marks of weathering, extending to a greater or less depth, and occurring in a variety of ways. In most cases this has occurred subsequent to their having been exposed to glacier-action. The most frequent form is that of channels or grooves hollowed out in the blocks (Fig. 4); organisms—such as fragments of Encrinites, &c.—project above their surface, but there are seldom any remains of the disintegrated rock found in them. This chemical erosion affects also the ice scratches, generally to a short distance only from the grooves. In others the surface has been eroded over a considerable space, whilst the remainder continues intact and the ice marks unaffected (Fig. 5). One glaciated limestone pebble, found *in situ* in the Boulder-clay, is split into four portions, and has other fractures in process of formation; the sides of the joints, as well as the outer surface close to them, have been affected by chemical erosion (Fig. 6). Other specimens of Carboniferous Limestone bear indications of a similar fracture and erosion having occurred since they were glaciated, but, being found in stone heaps, detached fragments only were obtained.

Quartzite pebbles have been met with in three

instances bearing grooves or channels very similar in appearance to those in some of the blocks of Carboniferous limestone; the most remarkable is large and rounded, and is such as might have been derived from the Old Red Sandstone Conglomerate of Scotland (Fig. 7); it was apparently solid, but the blow of a hammer proved it to be full of concealed joints, indicative of another form of prolonged weathering.

The most frequent form in which pebbles derived from stratified and slaty rocks show the effects of atmospheric action is by splitting into several fragments at joints. These are often found exactly in apposition. Occasionally but necessarily very rarely, one portion is separated from the other with a short distance between them; indicating the occurrence of a brief interval of time in the dropping of the fragments; the example exhibited (Fig. 8) is also covered on one side with glacial striæ; a portion of the other being eroded, as from the action of running water holding sand in suspension. This circumstance is not of very unusual occurrence. In other instances one or more pieces are split off from the original pebble, but still remain in apposition, whilst another surface, not in any way eroded, bears evidence that there has been a similar interval between its fall and that of the portion which is missing. Similar detached fragments of pebbles are constantly found in the stone-heaps, and frequently also in the clay. They must be portions which have split off and become separate since glaciation or other erosion has occurred.

A considerable amount of attention to the process of weathering, now taking place in various kinds of rock, has failed to afford evidence of the mode in which these erratic pebbles have been acted on. The examination of the whole series renders it evident that it has occurred

under exceptional circumstances; though exposed to such an amount of atmospheric disintegration as in many instances to render the rock rotten throughout, they have been so protected that the materials were not carried away by rains or the wash of water, but have remained in exact contact until they were deposited from icebergs on the muddy bed of this glacial sea, A careful consideration of the effects produced on them, and of the conditions of climate, &c., *known* to have prevailed at the time, have induced the conviction that they have formed portions of moraines on land, when, after having been repeatedly subjected to a succession of intervals of frost and thaw, a temporary change of climate has increased the snow-fall, and caused the glacier to extend itself, and in its progress carry forward this accumulation, as an integral part of its substance, into the sea, either directly or by uniting with another and main glacier, from which the bergs have broken off that conveyed away these boulders; that is to say, that an advance and retreat of glaciers has occurred similar to those of which there is record of having taken place at intervals in Greenland within 25 or 30 years.*

No opportunities have been afforded of examining moraine accumulations in which Granite or Trap rock enter to any amount into their composition; but there is no difficulty in the supposition that boulders of either, exposed to repeated alternations of freezing and thawing, might become disintegrated, and, if embedded in moraine débris, each particle would remain in its relative position. Such would be but an illustration, after prolonged repetitions in a compact rock, of what occurs, as

* "On the Fiords, Lakes, and Cirques of Norway and Greenland"; by Amund Helland, Fellow of the University of Christiania.—*Quar. Journ. Geol. Soc.*, vol. xxxiii, page 142.

a consequence of exposure to a single night's frost, in the case of chalk saturated with moisture, which on thawing immediately falls into innumerable fragments. A most remarkable collection of dark green blocks of rotten Trap rock, unmixed with other boulders, was exposed during the construction of the Bootle docks, where an immense number of them, embedded in a light green sandy matrix, formed an accumulation which was very conspicuous, its colour being a marked contrast with that of the Boulder-clay (see Section Fig 9). Its deposition must have occurred in the same manner as the patches of loose sand, frequently seen in the Boulder-clay, which have been derived from the disintegration of Triassic rock; the materials exactly resembling some moraine accumulations in the bottom of the valleys, being the base on which the Boulder-clay rests there, and probably has formed an integral portion of an iceberg from which it has dropped on melting.

Observations I have been enabled to make in a few examples of moraines containing rock-fragments of different characters are to no inconsiderable extent confirmatory of the opinion I had formed. At the southern extremity of the Longmynd, near Linley Hall, and near Batch, 3½ miles south of Church Stretton, there are accumulations of pebbles derived from the Longmynd Range, some of which being ice-marked confirm their glacier-origin. Amongst them were several broken into fragments, each of which, though entirely separate, remains exactly in apposition. The same is also the case in many, composed of Silurian grit found in the terminal moraine at Carnforth Station, Lancashire, and in greater proportion in a lateral moraine cut through by the tramway leading to the quarries at Warton Crag, belonging to the Carnforth Ironworks Company, in

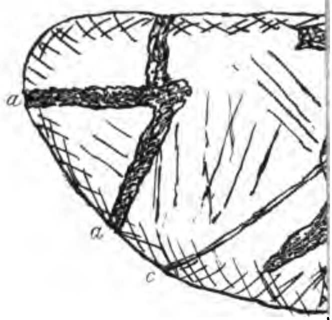
which, as well as at another lateral moraine in the approach to the back entrance to Morecambe Lodge, Yealand Conyers, a considerable number of glaciated Carboniferous Limestone boulders were also found split into two or many pieces, but still remaining in their relative positions.

It is impossible to conceive that, without the position of the fragments being disturbed, such fractures at joints could have progressed to entire separation, if the occurrence had taken place whilst they were situated beneath, or even when enveloped in a glacier; it is, therefore, evident that it must have happened subsequently; in all probability caused, as I have suggested, by having been repeatedly frozen and thawed whilst the boulders formed a portion of a moraine.

Many of the Carboniferous Limestone pebbles at Warton Crag, at Yealand, and near Leighton Hall, were not only glaciated but portions of their surface were also weathered in a similar manner to some in the Boulder-clay. Of each example corresponding forms have been found on those occurring in the latter; but the relative frequency of the occurrence of weathering is much less in pebbles in these moraines than in those in the Boulder-clay. This may be due to local causes; at these places the matrix in which they are embedded is a highly calcareous mud, and the tendency is much greater to form a calcareous deposit upon them than to occasion their erosion.

The presence in moraine accumulations of these weathered boulders, exactly resembling some found in the Boulder-clay, confirms the correctness of the inferences drawn from the examination of those in the latter; that they had formed integral portions of moraines until upon temporary increase of the glaciers to which they

1. Granite



4. Carboniferous Limesto

7. Quartzite.

owed their origin they were swept forward until, floating away in icebergs, they were deposited where found. The existence of them, both in moraines and also in the Boulder-clay, also illustrates what had been deduced from other evidences resulting from previous investigations in the Valley of the Mersey, that the accumulation of snow during what is called the Glacial Period in the different valleys of this portion of the British Isles was not greater than "might reasonably be considered due to the amount of deposition on their respective water-slopes." *

* "The Conditions existing during the Glacial Period," &c. By Charles Ricketts.—Proceedings of the Liverpool Geological Society, 1876–77.

EXPLANATION OF PLATE.

Fig. 1.—A block of weathered Granite broken off at a joint. Greatest diameter, 21 inches.

Fig. 2.—A similar mass of Basalt.—24 inches.

Fig. 3.—Weathered Silurian Grit.—4 inches.

Fig. 4.—Glaciated Carboniferous Limestone with eroded channels, from one of which a perforation passes through the block, a thickness of four inches, at an old joint.—14 inches.

Fig. 5.—Limestone, glaciated and eroded.—9 inches.

Fig. 6.—Limestone pebble, glaciated, eroded, and fractured into four fragments.—5 inches.

Fig. 7.—Rounded Quartzite, with weathered grooves.—6 inches.

Fig. 8.—Silurian Grit, glaciated and fractured; the fragments separate, as *in situ*.—3½ inches.

Fig 9.—Section at Bootle Dock.—*a.* Trias. *b.* Gravel and Sand. *c.* Boulder-clay. *d.* A light green sandy accumulation, containing numerous boulders of disintegrated Trap rock.

A REVIEW OF DR. F. V. HAYDEN'S GEOLOGICAL AND TOPOGRAPHICAL ATLAS OF COLORADO, WITH A SKETCH OF THE GEOLOGY OF NORTH-WESTERN AMERICA.

By Alfred Morgan.

The "Atlas of Colorado," lately published by the "United States' Geological and Geographical Survey of the Territories," under the direction of Professor F. V. Hayden, constitutes one of the most important contributions to geological science made during the year that has just passed away. By its means we are enabled to get a general and comprehensive view of the geology, etc., of that extensive and most interesting region; and to arrive at a more definite conception of the order, sequence, and extension of the great formations of the North-West. It may be regarded as the key to that vast geological system, which embraces within its compass the greater portion of the North American continent; and which is bounded on its eastern side by the Missouri and Mississippi Rivers, and on its western coast by the Pacific Ocean.

Geologists have been much indebted to this survey for many valuable publications relating to the former history of the western territories, and Reports and Monographs have appeared with a rapidity that attests the energy and enthusiasm of the corps. In these volumes we find great stores of information of a very varied character; but it was till now difficult to grasp the subject as a whole; and, it was only by comparing widely scattered information, that we could get any idea of the general outlines of the geological system.

Studied in part, many interesting problems suggested themselves, and enquiries were prompted as to their general significance, which we are now able to follow out with greater certainty, and at vastly less trouble to ourselves.

But, before referring to the Atlas in detail, I will ask your indulgence while I speak of the survey itself.

As many present will be aware there are several surveys in operation in the west, under the direction of departments of the United States Government. The best known of these is the survey of which Dr. Hayden is the director, and which is placed under the auspices of the Department of the Interior. There is also the survey over which Mr. Clarence King presides, and which operates "west of the 100th meridian." This latter survey is under the auspices of the Engineer Department of the War Office; and a reference to its publications, which are to be found in this society's library, will shew the very high character of its work. There are also the surveys of Lieutenant Wheeler of the War Department; and of Professor Powell, whose explorations of the Colorado River of the west, under the direction of the Smithonian Institution, promises a rich harvest of information.

As readers of *Nature*, of the 9th inst., would see by an interesting article of Professor Archibald Geike's, Congress will have before it, in the course of a few weeks, a proposal from the American National Academy of Sciences to reorganise the system on which the surveys are at present carried on. It not infrequently happens that a re-duplication of work occurs. Independent organisations, each pursuing an independent course, and taking no account of the work others have done in the same field, sometimes publish results of a discrepant

nature, and at other times give rise to bitter personal feeling and rivalry. The suggestions Mr. Geike advocates promise to alter this undesirable state of things; and, if adopted by Congress, the United States will soon have two surveys—one a topographical survey, and the other a geological one; by one or other of which all the work will be done upon a broader basis, and with even greater efficiency than at present.

The survey, of which Dr. Hayden is the geologist in charge, may be said to have taken its rise in 1867, when the state of Nebraska was admitted to the Federal Union; on which occasion Congress voted an unappropriated fund for the purpose of a survey, of which Dr. Hayden had the direction. The work occupied two years, and so well did Dr. Hayden carry it out that, in 1869, he began that series of explorations under the Land Office which, in a year or two, became the United States Geological and Geographical Survey of the Territories, of the Interior Department, and which has made his name celebrated both in Europe and America. This widespread recognition of his services to science must be very gratifying to Dr. Hayden; and the zeal and intrepedity with which he has organised his forces, has produced an *esprit de corps* among all the members of his staff which is at once apparent to the reader of his interesting reports. It is pleasant to find that, though differences of opinion exist among his eminent colaborateurs, each discusses the question at issue from his own individual stand point, with that deference and respect that ought always to characterise the utterances of truth lovers, and truth seekers. A subject of enquiry does not present, for instance, the same aspect to the palæophytologist as to the palæozoologist; and due allowance is justly made for "personal equation" in the discussion of it,

Dr. Hayden invites each writer to express his own views fully and unreservedly without regard to other's hypotheses or previous theories.

Glancing at the contents of the volumes that have already appeared, the territories surveyed range from Montana in the north, to New Mexico in the south—an immense stretch of some 18° of latitude. The reports for 1870-2 made known to the world the wonders of the Yellowstone country—its magnificent geysers, and its enchanting fairy-land of crystal grot, unique in its picturesque beauty. So great was the interest that was awakened that Congress set apart the entire territory—equal in extent to the whole of Wales, as a National Park—never to be spoiled—the recreation ground of the Continent, the North American Wonderland.

In 1873, owing to the hostility of the Indians, the field of operations was transferred to Colorado, and now as the result of four years work devoted to the survey of the state, we have in our hands this very beautiful atlas.

In looking through the volumes that have been published by the survey we notice the variety of subjects that have been investigated. In fact, there is scarcely any department of natural science that has not benefitted by the labours of the survey. Ornithology, Zoology, Botany, Entomology, Geology, Palæontology, and Ethnology are subjects, on which much has been published, while Antiquities and Archæology, together with Economic Science and practical knowledge have not been omitted from the series.

The elaborate Memoirs of Professors Coues and Allen, on the "Rodenta;" of Dr. A. S. Packard, on the "Geometrid Moths;" of Professor Cyrus Thomas, on the "Acrididæ;" of Professor Meek, on the "Invertebrate Palæontology;" of Professor Cope, on the "Cretaceous

Vertebrates;" of Professor Lesquereux, on the "Tertiary Flora," are works of which it is scarcely possible to speak in terms of too high commendation.

The Atlas is an eminently practical work. As a guide to the miner and emigrant, it possesses a high value apart from its scientific worth. As a publication, it equals those of a similiar character which have been issued in Europe. The sumptuous excellence of its typography and lithography entitle it to rank with those *livres de luxe,* which have from time to time, issued from the National Imprimerie of France. And, as we examine the details of the work, and remember that we are indebted to the large handed liberality of the United States Government, not only for it, but for so many other valuable donations to our library, we cannot but wish that the same enlightened generosity were manifested by our British Administration, and that those prohibitive prices at which so many English survey publications have been published, were for ever abolished. It is, perhaps, too much to expect, that societies like ours should participate in a free distribution of the maps and reports of our surveys, but it is only reasonable to ask that all such publications should be issued at prices which will not put them beyond the reach of those students who though ardent lovers of science, have to watch very carefully over their expenditure.

The first four sheets of the Atlas are devoted to a general description of the trigonometrical base lines, the drainage systems, the economic features, and the outline of the geology of the country. We are able to see at a glance what is the extent of agricultural land, the area of pasturage and forest, the proportion of sage bush and bad lands, the range of mineral tracts, and the expansion of elevated districts situated above

timber line. We have thus condensed in small compass the information of a useful nature which it would necessitate extensive reading to acquire:—

I. The Triangulation Map.—The chief topographer of the suyvey was Mr. James T. Gardner, and his method of triangulation, &c, may be briefly described.

The horizontal measurements were made by a connected system of large and small triangles, developed from a measured base near Denver. Four miles of the primary base line were measured on the track of the Railway and two others over very level ground. Its length was twice measured with a steel tape and every precaution used for pressure and temperature effects. The tape was under 20 lbs. strain and the temperature was taken every five minutes. Triangular pyramids 30 feet high were erected on the plains by which the triangles were extended to the mountains, where roughly-built stone monuments were used to sight at, and the height of summit was so taken. The angles were measured with an 8 inch circle graduated to 10 inches and reading to 5 inches. The measurements were generally repeated six times on different parts of the circle.

Asimuths were observed at the principal stations by repeated observations between Polaris and an illuminated signal. The co-operation of the U. S. Coast Survey was also given. The mean error is less than 2 feet per mile. This is usually determined by the closure of the triangles, whose observed angles should sum up to 180°, less the spherical excess.

The secondary triangulation was carefully carried out and the topography sketched on frequent occasions. The railway levels were used and extended, and, as a whole, the work was so well done that it is felt to be an adequate basis for all future work.

II. THE DRAINAGE MAP.—On this sheet is depicted in a very beautiful manner, in very delicate blue lines, the tributary streams and rivers of the country. The entire system of watershed is clearly revealed. The main and secondary 'divides' and the symmetrical outlines of the hydrographic areas are all clearly indicated.

III. THE ECONOMIC MAP.—This is an eminently useful sheet, and holds out quite a tempting invitation to colonists. The mountain regions—more particularly in the neighbourhood of the parks—is fertile and grassy, and well adapted for dairy purposes.

Most of the hard vegetables and cereals Dr. Hayden observed growing at heights of 6,000 to 8,000 feet, and the number of agricultural settlers is rapidly increasing.

Mining has been vigorously carried on. The little streams cut deep gorges, or gulches, and along these careful search has been made for gold, &c. Some of these are very rich; and wonderful stories of productive placers and rich lodes are told in the Report for 1873.

IV. THE GENERAL GEOLOGICAL MAP.—The lithological series is set down as—

9. Quaternary.
8. Tertiary.
7. Post Cretaceous.
6. Cretaceous.
5. Jura-Trias.
4. Carboniferous.
3. Silurian.
2. Metamorphic Rocks.
1. Eruptive Rocks.

The four maps just referred to are on the scale of 12 miles to an inch, and constitute the first series of the Atlas. Before proceeding to notice the other maps included in the atlas I will endeavour to sketch—

I can only do so in very general terms, however, and shall endeavour to trace it in its comparison with the formations elsewhere developed in the north-west.

1. Eruptive Rocks—*Archæan.*—These form the neucleus of the mountain chains. They consist of a great series of granites, schists, and gneisses, with minor masses of eruptive rocks, all thrown into a very complex system of folds, which are very difficult to trace, on account of the absence of any permanent features and any one horizon. Metamorphism has effectually obscured the destinctive marks which may sometimes be observed in a limited area.

This crystalline unstratified series underlies the stratified deposits. It possesses a uniform character throughout the whole of the Rocky Mountain range. Mr. Marvine speaking of it* says: "considering the extent and antiquity of the formation, and the probable mutations of its history, its lithological character as a whole seem to be remarkably simple and uniform. From quartzite through siliceous and mica schists to very simple varieties of gneiss and granite, in which the mica is wholly subordinate, and the feldspar mostly a tabular and twined orthoclase, with mostly one or two triclinic feldspars present, and the list of rocks is complete."

Great areas are composed of simple feldspathic granite, almost structureless, which generally eventuate in the "dome" form of outline; an outline which is probably developed by the eroding forces of climate. There is an interesting fact, to which Dr. Hayden calls attention in his Report for 1873, relating to the group of sedimentary strata. He says that no important flexures have been

* Report 1872, p. 137.

discovered in them, though such may have existed in the metamorphic rocks. The inclination of the beds is, in some places, very great. Sometimes the uplifted zone is ten to fifteen miles in width, and composed of a great number of ridges, called in the country "hog backs;" the inclination of these from the granite nucleus outwards to the plains is not more than from 10° to 25°, gradually diminishing until the liquitic attains its unbroken horizontal development.

In an another locality it will be seen that the entire group of strata are crowded into a space of a mile or less, and stand in a perfectly vertical position, which is suddenly found to terminate abruptly and the horizontal arrangement to prevail.

We see that to whatever extent the metamorphic mass that forms the nucleus of the ranges may have been afflicted by the shrinking of the crust, etc., the sedimentary strata have been simply lifted up, in a more or less vertical manner; and the conclusion is forced upon one that, in a former epoch, they extended in an uninterrupted series over the region now occupied by the mountain ranges.

So far as one can judge the process of upheaval was a slow one, of long duration, and of uniform action. In many instances the sedimentary group seems to have resisted the central force, and thus the strata were broken off and the edges turned up very abruptly. In others the uplift seems to have influenced the strata for long distances, and the beds indicate a very slight inclination, not one extending for a long distance.

THE GREAT DIVIDE.—This extensive development of the eruptive rocks forms the backbone of the North American

---

* See page 20.

Continent, sending its store of waters on the one side to the Atlantic, and on the other to the Pacific Oceans. It extends in a great series of elevations from North to South, including in its vast system numerous minor ranges, and being in some parts six or seven hundred miles in breadth.

A very interesting book of travel, by Lord Dunraven, bears for its title "The Great Divide," and gives in a lively and agreeable style a good description of the country, which may be read with pleasure by the geologist, as well as by those who delight in adventure.

The entire range of the Rockies may be said to extend from Colorado in the East, to the Sierra Nevada, of California, in the West. But, they do not present an unbroken chain. On the contrary, they are broken up into many minor ranges, and throughout the district more immediately under our notice this evening they are broken up into many ridges, the sides of which are cut up by myriads of deep gorges, and which inclose, as within walls, large areas to which the name of 'Parks' has been given. The streams which rise in the higher regions flow down the gorges, and cutting through the fertile plains persue their ocean-ward course along deep and rugged cañons. And everywhere are to be found vast deposits of drift and moranial matter and huge amphitheatre shaped hollows that attest the intensity of a remote glacial period.

The North, Middle, and St. Louis' Parks are the larger of the many sheltered basins which lie nestled among the mountains, and their beauty and fertility is such as to have entitled Colorado to be called the most picturesque state in the Union.

Lord Dunraven, speaking of them says—"Of all sizes, from a few acres to many hundreds of miles in extent, they lie, fertile, clothed with grass, decked with

flowers, sparkling with silver streams, oases amid the savage barrenness of the mountains. They are not only beautiful, but useful, and answer a very wise purpose in the economy of nature, for acting like huge reservoirs, they collect the thousand rills that start out from under the everlasting snows, and become the sources of great rivers."

2. *Metamorphism.*—This force it would appear, was deeply seated and acted upon all the rocks, including the granite, *in situ,* but so many questions arise in this connection that I cannot now refer to it at length. Nearly all the metalliferous deposits, for the profusion and richness of which Colorado is so celebrated, occur in viens in the metamorphic rocks or in their *dêbris.*

3. *The Silurian* is represented by a series of strata corresponding in general characters with those of Europe. One peculiarity, however, I may mention. In Park Range the trachytic beds appear to be interstratified with the older sedimentary rocks. The aqueous layers vary much in thickness. In some places a thousand feet thick, they diminish to a few feet in a short distance, and in some places are interstratified with the silurian quartzites as though of the same age with them. It is probable they are not older, however, than the Tertiary period, and merely exhibit a phenomenal peculiarity.

Near Cañon City and Colorado springs, the silurian beds are finely developed. The beds rest unconformably upon the granitoid rocks with 600 or 800 feet of reddish limestone superimposed, containing characteristic fossils. Dr. Hayden thinks there is no doubt this formation underlies the entire country east of the Rocky Mountains.

4. *The Carboniferous.*—This period in geological history is distinctly marked in North America. If we study its development over the entire continent we may regard it

as being more strongly defined than anywhere else on the world's surface, so far as is known. Its synchronism with the European development is very close. Dr. Newberry has put down the area of the U. S. Coal field of carboniferous age as 150,000 square miles in extent, reaching from New Mexico and Texas, along the Mississippi Valley and the New England States to Nova Scotia and Melville Island. But, in the west, and indeed in the central portion of the continent, the sea must have prevailed during the Carboniferous epoch, and we only find a series of massive limestones—the product of organic life in a shallow ocean, perhaps, but one full of vitality. In Colorado the characteristic fossils are *Spirifer, Productus, Crinoids, and Corals* The dip is very slight, scarcely 3°, except where the edges of the beds are turned up against the Mountain Ranges.

Abundant invertibrate fossils have been found, but the results of the examination of them are not yet published.

5. *The Jura Trias.*—It often happens that the lower members of the sedimentary series are absent, and resting directly upon the smoothed, though often irregular surface of the Archæan Rocks, and forming the lowest member of the exposed stratified formations, is a series of sandstones which varies in thickness from 500 to 2,000 feet, and of which the colour is so striking and so predominent a character, that they are denominated the "Red Beds."

Conglomerates are found at different heights in the series, but, generally, near the base, and would appear to be derived from the adjacent rock. In the lower portions the beds are so evidently made up of the material of older rocks near by that it is difficult to distinguish, when metamorphism has operated, the

jurassic sandstone from the underlying granite. Dark red is the prevailing colour, but other tints are found.

Lying immediately over the red beds are a more shaly series of rocks, which have been referred by Mr. Marvine to the Jurassic. The arenaceous element still predominates, but agillaceous material is present to a large extent, and seams of impure limestone and gypsum occur. The prevailing colour is still red, but many beds of variegated aspect are are found.

In Colorado, as far as I am aware, no fossils have been obtained from the Triassic beds, but in the upper Missouri country Dr. Hayden found in them a species of ostrea and fragments of *Pentacrinus asteriscus*, a characteristic jurassic fossil.

The Red Beds are usually termed in the Reports, &c., Triassic, but it is by no means proved that they are so. Beds of an analagous nature are found in the Carboniferous and in the Jurassic. They are put down in the Atlas, provisionally, as Jura-Triassic: and it may eventually appear that the Trias is wanting.

Geographically, it is one of the most widely distributed formations of the west. From the northern boundary to the southern line this formation makes its appearance wherever a mountain range is elevated so as to expose the various sedimentary groups.

One of its most striking developments is seen in the "Gateway of the Garden of the Gods," where immense masses rise like a protecting wall, leaving a narrow cañon like opening—the so-called gateway.

6. *The Cretaceous*.—This formation attains a thickness of 4,000 feet in the north-west, and may be said to occupy a greater surface area than any other group in North America.

The Cretaceous era was probably one of subsidence, and to the east of the Rocky Mountains was one great sea, having a width of 100 miles or more, and extending from the Arctic regions to New Mexico. A vast region, that was previously covered with forest trees, became gradually submerged and covered up with calcareous deposits.

The lowest division of the Cretaceous, corresponding to the English Gault, consists of a series of thick-bedded coarse sandstones and conglomerate, and contains numerous impressions of dicolyledonous trees with beds of liquite. Its lithological characters indicates that it was formed from the immediate *débris* of the land, and gradually submerged. It has been termed:—

The Cretaceous No. 1; or, the Dakota Group. Its texture and composition are extremely variable, and Dr. Hayden is inclined to regard it as transitional, between the Jurassic and the Cretaceous series; but, in other respects, it is so permanent, and so readily recognised, that it is always regarded as the true base of the Cretaceous system of the west.

Professors Meek and Hayden were the first to classify the vast thickness of the formations included within the Cretaceous system. Their observations commenced near the source of the Missouri River, and the terms they employed have been used to describe those extended deposits found along the eastern base of the Rocky Mountains, and as far north as New Mexico. The classification embraces five distinct epochs, in each of which we find well marked differences, both in the character of the rocks and in their included forms.

The opinion was formerly held by some observers that the Dakota Group was of fresh water origin; but when we find it covering an area of 60 miles in width,

and extending from Texas to the northern limits of Minnesota, thus passing through fourteen degrees of latitude, and perhaps extending across British America into Greenland, it is difficult to imagine a fresh water formation of such magnitude. It preserves a remarkable similarity throughout, and has not yet yielded any vertebrate fossils.

The character of the leaves found in the Dakota Group is not that of a dry land flora, nor yet that of bogs or peat. The most abundant remains are those of Sassafras, which is a species that grows in the present day in every kind of ground and station.

The group merges imperceptibly into the higher member of the series. It has been extensively studied in the Missouri country, Kansas, and Nebraska, where it attains its greatest development. In Colorado it attains some 1000 feet in thickness. The leaves found in it are of a higher type than those occuring in Europen Cretaceous strata, and much discussion took place as to their true geological age. Professor Heer was inclined to class them as Miocene, and in this view he was supported to some extent by Dr. J. S. Newberry, but it is now the generally accepted opinion that the Dakota Group constitute the base of the American Cretaceous formation.

Palæophytology has been too often considered as of little importance in regard to the determination of the age of geological divisions. But, in this instance, we have a proof of its value as a guide; for it is only by the study of the flora of the Dakota Group that its relation to the Lias, the Jurassic, or the Cretaceous has been decided. Well preserved casts of *Pharella Dokotensis*, *Axinea Siouxensis*, and *Cyprina arenaeea*, indicate the marine origin of the group. Among its plant remains are to be found leaves of—*Populus*, *Salix*, *Alnus*, *Ficus*,

Platanus, Liriodendron, Sassafras, Magnolia, etc. It is interesting to note that a flora of so modern an aspect existed in these early times, and it is not to be wondered at that Heer and others long hesitated before accepting the evidence of its cretaceous age.

Dr. Newberry remarks:—"Vegetation was revolutionised at the close of the Triassic period, when the aquadaceous flora, which then prevailed on the earth's surface, was succeeded by the reign of angiosperms, in the introduction of a hundred or more species of forest trees, in great part belonging to the genera now living."

A similar flora still flourishes in the Southern States of America. The great fan palms discovered by Dr. Hayden are the only plants that have a really tropical character, but they are associated with poplars, sycamores, hazels, &c., which indicate temperate conditions of climate. The European Miocene contains tropical plants, such as *cinnamomum, thakea,* &c., which are absent from the Miocene of the west.

Cretaceous No. 2—Fort Benton Group. This group consists of dark laminated clays, with occasional seams of grey limestone, and with the foregoing group may be correlated with the lower chalk of British geologists, and the *Turonien* of D'Orbigny. Its principal fossils are, *Inoceramus problematicus, I. fragilis, Ostrea congesta, Ammonites* (several species), *Nautilus* (?) etc.

Cretaceous No. 3—Niobara Division. About 300 feet in thickness. Consists usually of chalks or shaly limestone, and marls, with beds of gypsum, with very numerous fossils of characteristic Cretaceous species, fish scales, &c. This group complete the lower division of the Cretaceous series of the north-west. It is not developed so largely in the southern portions of the country as it is in the Missouri region.

CRETACEOUS No. 4—FORT PIERRE GROUP. The thickness of this group is about 700 feet, and it attains its greatest development in the Missouri country. It consists of a series of dark coloured plastic clays, with veins and seams of gypsum in its lower portions, and reposes conformably upon No. 3. The upper part has among its fossils *Nautilus Dekayi*, *Ammonites placenta*, *Baculites ovatus*, *Scaphites nodosus*, ect., with bones of *Mosasaurus Missouriensis*. The lower portion has *Inocerami*, *Helioceras* (several species), etc., and abundant fish remains. In Colorado the different members of the series that correspond to Nos. 2, 3, and 4, have been ranged together as "The Colorado Group," and they attain there their greatest development.

CRETACEOUS No. 5—FOX HILL BEDS. Grey, ferrugenous, and yellow sandstone, and crenacous clays. Thickness in the Missouri region 500 feet, but in Colorado 1,200 feet or more, including many beds of shaly limestone. Fossils:—*Belemnitella bulbosa*, *Scaphites conradi*, *Fusus* (several species), *Cardium subquadratum*, etc., with a great number of other molluscous fossils, and bones of *Mosasaurus*.

This group, and the previous one, correspond to the upper or white chalk and Martricht beds, *Senonien*, of D'Orbigny.

All these groups have been carefully studied by Dr. Hayden; and, though marked changes occur in the lithological character of the beds composing the several series, he has been able, by following them continuously in every direction, from their typical development in Upper Missouri, to their extreme attenuation in the south-west, to fix the identity of each wherever it appears; though, he confesses, that after leaving the Missouri region, he does not find those strongly defined lines of separation, of either a lithological or a palæontological nature, which exist up there.

In Colorado the only leaf remains discovered in No. 1 formation were found by Dr. Peale, in the South Platte district, and Professor Lesquereux decided that they belonged to *Proteoides acuta* (Heer).

7. Post Cretaceous. Between the Cretaceous and the Tertiary formations there has hitherto existed a great gap, and, except for the Aix la Chapelle flora, I do not know of the discovery of any remains of exogenous vegetation prior to the Eocene. Dr. Debey, who examined the Aix flora, estimated the number of species as being over 200, of which 67 species were crytogamous. Among the phœnogamous forms Conifers were abundant, the most common belonging to the genus *Cycadopteris* (Debey), are almost identical with *Sequoia*.* As a whole the remains present a remarkable affinity to the Dakota No. 1 group.

The term "Lignitic Group" was usually used to describe those beds that overlie the Cretaceous, No. 5 series, or Fox Hill Group, but as, in the west, especially along the fortieth parallel and southwestward, there are very thick beds of coal in the Cretaceous formation, extending down even into the Jurassic, the term is now abandoned. But there is no doubt, the Fort Union Beds of the Upper Missouri are the equivalents of the Lower Tertiary of the Rocky Mountains in Colorado.

From an economic point of view the importance of this formation cannot be over-estimated. It is to the west what the great appalachian coal region of Carboniferous age is to the east. From a number of analyses, I find the proportion of fixed carbon is about 52 per cent. in the Lignitic Coals. The European lignites average 45 to 46 per cent.

---

* Lyell, "Elements." 6th Edition, p. 331.

The aggregate thickness of the beds composing the Lignitic Group may be said to be 2,000 feet or more; they are described as—Beds of clay and sand, with round ferruginous concretions and numerous beds, seams, and local deposits of lignite; great numbers of dicotyledonous leaves, stems, etc., of the genera *Platanus*, *Acer*, *Ulmus*, *Populus*, etc., with very large leaves of fan-palms; also *Helix*, *Melania*, *Vivipara*, *Corbicula* *Unio*, *Ostrea*, *Potamomya*, and scales of *Lepidotus*, with bones of *Trionyx*, *Emys Compsemys*, *Crocodilus*, etc."

From this description it will be, at once, inferred that at the time of its deposition there existed a flourishing vegetation far exceeding in luxuriance anything now to be found in those latitudes.

From our study of the Upper Cretaceous beds we see that they are of a marine origin, but when we arrive at the base of the lignitic group, we find every indication of shallow turbulent waters, and many signs of the existence of an altered condition of things.

Dr. Hayden points out that whenever any invertebrate remains are found above the lowest member of this group they are invariably of brackish or fresh water types, while all below it are of marine species. He continues—"are not these changes sufficient to indicate clearly that these beds are transitional between the Cretaceous and Tertiary Epochs? We find also a complete change in the vegetable as well as animal life. We are not aware that any of the vertebrate remains which have been regarded by Cope and Marsh, Report, 1874, p. 29, as proving the Lignitic group to be of Cretaceous age, have ever been found mingled with any other forms of life of strictly marine origin. So far all the vertebrate fossils have been discovered in the Lignitic group. It seems therefore that not a single

species of vegetable or animal life survived the physical changes which were introduced during the time of the deposition of this group." No purely marine mollusca pass above this horizon. Estuarine and brackish water types appear, and gradually give place to fresh water forms.

It may matter little whether these beds are denominated Upper Cretaceous or Lower Eocene, but it is important to recognise in them a boundary line, or landmark in the geological history of North America, and eminent vertebrate-palæontologists who pronounce them to be Cretaceous from their own particular point of study do not claim that a single species of vertebrate life passes above the well defined horizon I have referred to. Dr. Hayden says in this connection:—

"I hold the position that the sequence of all formations is to be sought for in all places; that while breaks not unfrequently occur, the normal condition is the entire absence of any line of demarcation, so that with the closest scrutiny the geologist cannot tell where one formation ends and another begins."

Speaking of the extent of the Brown Coal in the United States, R. C. Taylor says *: "Nature has indeed worked on a grand scale. We see here a deposit of brown coal, extending from the Rocky Mountains of Colorado even to the Polar Sea. A deposit so extensive that the magnitude of its proportions is far from being defined: yet enough is known to show that it exceeds in longitudinal range and breadth all others of the present surface of our planet. So far seems to be established, that, allowing liberally for interruptions of continuity, supposing that any such exist. It occupies an area equal to twice the size of Great Britain."

* Statistics of Coal," 1843.

Prof. Lesquereux, in his splendid monograph on the Tertiary Flora (Washington, 1878), pays an eloquent tribute to Dr. Hayden, which, did space permit, I should like to have quoted. It is to Dr. Hayden's zeal and wonderful ability that the world is indebted for the accurate knowledge we now possess of what so few years ago was a *terra incognita* both to the geographer and to the geologist.

Dr. Hayden began his investigation of the group in 1854 on the Missouri, near Fort Clark, and followed the formation up the Yellowstone for about 600 miles. There is no doubt the series extends into high northern latitudes, and my question of those who have made Arctic Geology a special study would be—Is the so-called *Miocene* flora of Disco, &c., not really an extension of this undoubtedly Lower Eocene series?

There appears to be no doubt as to the identity of the lignitic series of Canada with those of the north-west. Prof. J. W. Dawson, of Montreal, says:—"The plants of our lignitic strata are for the most part identical with those found by American geologists in the Fort Union series. . . . They approach very closely the Miocene floras of Europe." He then adds: "If we were to regard the affinities of the plants merely, and to compare them with the Miocene of other countries, and also to consider the fact that several of the species are identical with those still living, and that the whole facies of the flora coincides with that of modern temperate America, little hesitation would be felt in assigning the formation in which they occur to the Miocene period. On the other hand, when we consider the fact that the lower beds of this formation hold the remains of reptiles of Mesozoic types, that the beds pass downwards into rocks holding *baculites* and *Inocerami*, and that a flora essen-

tially similar is found associated with cretaceous remains, both in Dakota and Vancouver's Island, we should be inclined to assign them at least to the base of the Eocene."

8. Tertiary.—During the Tertiary period the whole of the western portion of America was covered with immense lakes. As the period advanced many smaller lakes were formed, and in the Pliocene era thousands of small lakes existed, and their basins and peculiar deposits are seen in great profusion all over the country.

The great lignitic group may be regarded as the base of the North-Western Eocene. It is succeeded in the Wind River Mountain region by a great thickness of sandstones, containing fragments of *Trionyx Testudo, Helix Vivipara*, &c., which attains to some 1,500 feet of thickness. Whether these beds are of Eocene or Miocene age is doubtful. We find, however, the typical development of the Miocene in what is termed the White River group: thickness 1,000 feet. Its greatest development is in the "Bad Lands" of White River, and its lithological series consists of white and drab clays, with sandstone and limestone. The fossils are of great interest, and include *Oreodon, Titanotherium, Rhinoceros, Hyænonodon*, &c., &c., all extinct. There are no brackish water or marine remains.

The Pliocene beds of the Upper Missouri attain 300 to 400 feet in thickness, and contain remains of *Canis, Felis, Castor, Equus, Mastodon*, &c., some of which are very closely allied to living species.

I cannot conclude my paper without referring in a special manner to the second series of maps contained in the Colorado Atlas, twelve in number, plotted on a scale of four miles to the inch, viz., six topographical sheets, and six corresponding maps, geologically coloured.

The topographical details, though numerous, are so selected as not to neutralise or interfere with each other, and each presents a clear and broad picture of the country. The contour lines are 200 feet apart in vertical distance, and in them we see the surface configuration laid down with all the clearness of a model. "We can follow the lines of the broad valleys, of the deep narrow cañons, and of the hundreds of minor tributaries, which have scooped out their courses on either side. Here we look down upon a vast table land, deeply trenched by stream channels; there upon a succession of bold escarpments or mesas which bound the table-land and hem in the neighbouring valley."

The high mountain-ranges which rise from these extensive plains are vividly depicted, and yet no shading is employed. All the effects are produced by contour lines, so faithfully set down that a single line may be traced in all its sinuosities along the whole of a mountain's front, until it comes out upon a table-land beyond. This method of expressing the peculiarities of surface conformation seems to be an improvement upon that adopted by our English map-makers. Who has not felt the annoyance of poring glass in hand in a vain endeavour—as, alas! it so often is—to read the names printed on our own Ordnance Survey maps. Very admirable productions, as they undoubtedly are, our British Survey maps are so overloaded with dark heavy shading that a steep hill side, which may perhaps be only a few hundred feet in height, looms upon the sheet with all the lowering blackness of a great mountain.

The system of plotting maps with elevation curves is one that will commend itself to the practical geologist, not only by reason of its greater clearness, but because of the help it will afford him in his work. Geological

maps will always represent in curved lines the boundaries of formations, and it is evident that where strategraphical details have been carefully worked out, a map that shows in addition to outline curves, those of vertical distances or elevation, will present with great accuracy results which it would otherwise require much time and labour to make out.

Following in order after the geological maps are two sheets of vertical sections. The allusions I have already made to the structure of the Rocky Mountain ranges render it unnecessary to say much more on that subject in this place. We notice that in some parts the force from beneath seems to have acted so nearly in a vertical direction, that only the lignitic or perhaps a portion of the underlying cretaceous strata are exposed on the flanks of the ridge, and the operation of upheaval has not materially disturbed the rocks except in the immediate neighbourhood. There is no doubt but that the sedimentary formations were once continuous over the regions now occupied by these lofty peaks. The missing portion of this unbroken series has been eroded during the long slow process of elevation.

Although there is such simplicity in the dynamics of these ridges, and the geological series is developed on so simply-grand a scale, yet there is much complicity in some of the details. Perhaps one of the most important lessons that is taught by the study of the Atlas in conjunction with the Reports and monographs, is that there are so very numerous a set of phenomena that result from erosion. The Glacial period has left wonderful exhibitions of its power. Even the highest peaks have suffered more or less degradation, and the amount of material that has been carried away from the great central mass must have been enormous.

Water and Ice are still at work diminishing the height of the loftiest ranges, but their force is now infinitesimal in comparison with that of former times. Dr. Hayden reckons that the work of disintegration has been going on ever since the Carboniferous period. In the panoramic sketches we see, too, the indications of the more recent results of earth-sculpture, and indications of glacial moraines, lake-deposits, drifts, sand-dunes, &c.

In presenting the two sheets of scenery sketches, Dr. Hayden has conferred a boon upon us that we shall all appreciate; and, in this connection, I will refer to a singular group of rocks belonging to the Lower Eocene, to which the name of the Monument Creek group has been given. They are depicted on the chart. The name of Monument Park has been given to the locality where the group is most extensively developed. The peculiarity for which the series is remarkable is that subaërial denudation has sculptured out most singular monument-like forms, from the remarkable aspect of which the place derives its name. The sandstones forming the group vary considerably in colour and texture—now a fine-grained arenaceous rock, then a coarse conglomerate composed of granital detritus loosely cemented together; now of a milky white colour, and again of a red or variegated hue.

In some parts of the Park we see the mesas capped with trachyte, which, ascending in dykes at a remote period, overflowed the surface. Much of this trachyte is a coarse breccia containing large pieces of sandstone, which were caught by and enclosed in the melted matter. The layer that caps the columns or monuments is of the same character as that forming the summit of the buttes or mesas, and had the same origin. Acting as an umbrella, it protected to some extent the sandstone for-

ming the shaft of the column from the force of eroding agencies, until wind and frost slowly yet surely asserted their sway, and the soft friable sandstone became dissolved.

In the "New World" we find the greatest development of the oldest sedimentary rocks, the Laurentian. Whether we regard the *Eozoon* as an organic or as an inorganic substance, the fact that extensive series of limestone occur in the formation points to its organic origin, in part at least, and indicate that it is built up from the ruins of an ancient continent. It is generally regarded as the most ancient portion of the Earth's surface. And though in the far west the Laurentian is buried, where it exists, beneath newer formations, we may suppose the Silurian strata to be made up of its ruins. It is most interesting to trace the tide of development in its progress over that great continent, and the fact that *Onoclea sensibilis* has been found on the Island of Mull but not on any other European Tertiary, while it is comparatively abundant in the American Miocene, is an important one. And it would seem that if an exodus of plant life set in from America to Europe, it was probably along a temperate zone.

It would, I am sure, gratify Dr. Hayden, with whom I have had the pleasure of corresponding for several years past, and to whom as a Society we are so largely indebted for generous gifts to our Library, if, as the result of my effort to interest you in the work he has accomplished and is still so actively pursuing, I might convey to him an appreciative expression of our recognition, as a Society, of his unparalleled success as an explorer and as one of the leaders of scientific advancement. This, I am sure, you will do. And I conclude my paper by expressing the hope that ere long we shall

see published a *resumé* of the work that he has accomplished; for, at present, it is no easy task to reduce and correlate such a mass of facts as are published in isolated volumes, not always available when wanted; and if Dr. Hayden himself were to undertake such a work, his extensive knowledge and great experience would find a most appropriate field, and all students of both British and American Geology would rejoice to see it.

⁂ In the discussion which followed the reading of this paper the highest admiration of Dr. Hayden's work was expressed by several members of the society.

ON SOME GLACIAL STRIÆ ON THE NORTH WALES COAST.

By Aubrey Strahan, M.A., F.G.S.,

H.M. GEOLOGICAL SURVEY.

By permission of the Director-General of the Geological Survey.

The following instances of striated rock surfaces have been met with during the summer of 1878, on and near the coast between the Ormes Head and Holywell:—

Great Ormes Head, by the side of the New Drive, near the East Lodge.

Under Boulder-clay, on a steep limestone slope facing S.E. The projections of the rock are smoothed and glaciated, but not strongly; two sets of striæ cross nearly at right angles.

(*a*.) Running horizontally round the cliff; direction, N. 26° E.

(*b*.) Running straight down the slope, more distinct than (*a*); direction W. 20° N. to E. 20° S.

Height above Ordnance Datum, about 50 feet.

The Sychnant Pass, near Conway.

A striated boss of felstone by the side of the high road. Striæ run down the slope from N.W. to S.E. Height above Ordnance Datum, about 300 feet.

On the brow of Craig Cliff, near Llandulas Station.

(*a.*) On a nearly vertical face of limestone forming the east side of a small hollow filled with Drift, and leading up to the air-shaft of the railway tunnel. S. 10° W. to N. 10° E.

(*b.*) On a nearly horizontal limestone surface, a few yards east of the hollow mentioned above. Direction N.E.

Height above Ordnance Datum, about 70 feet.

Quarry on South Side of the High Road above Llandulas Station.

Large glaciated surface exposed by the removal of three feet of Boulder-clay. Striæ long, not perfectly straight. The ground slopes to the north. Direction N. 30° E.

Height above Ordnance Datum, about 250 feet.

Moel Hyraddog, near Dyserth.

Under a small patch of gravelly Boulder-clay, on a terrace of limestone on the east side of the hill. The ground slopes to the E.N.E. The striæ are constant in direction to the N.E.

Height above Ordnance Datum, 750 feet.

Craig Fawr, near Dyserth.

On a projecting shoulder of limestone, at the foot of a very steep rocky slope, near the Newmarket and Meliden Road. The slope faces west, and overlooks the

New Red Sandstone plain. The striæ sweep round the shoulder of rock *horizontally.* Not one comes down from the slope above. The projections of the rock are well smoothed and striated on the sides facing the north. Direction of flow, N. to S.

Height above Ordnance Datum, 160 feet.

Limekiln near Pen-yr-Allt, Gwaenysgor.

The surface of the Limestone is thoroughly smoothed and striated under two feet of Boulder-clay. The ground slopes from N.E. to S.W. Direction of striæ, N. 5° W.

Height above Ordnance Datum, 660 feet.

Chwarel Pen-y-Gelli, near Holywell.

Under a thin covering of gravelly Boulder-clay. The scratches are short, and not constant in direction. The ground slopes to the south. Two sets cross obliquely—

(*a.*) E. and W. (*b.*) E. 15° N.

Height above Ordnance Datum, 700 feet.

Quarry on Pen-y-ball, near Holywell; at the North end of the tunnel on the Tramway from Holloway.

The rock is overlain by about one foot of gravelly Drift, containing striated blocks of Limestone. The prominences only of the rock-surface are glaciated. The ground slopes to the N.N.E. Direction of striæ N. 35° E. and N. 40° E.

Height above Ordnance Datum, 815 feet.

RECENT AND FOSSIL NASSA.

By F. P. Marrat.

It is by no means a difficult matter to see that the whole of the shells in this genus are simply varieties of each other; at the same time it would be a most difficult undertaking to prove it to persons who have not studied the subject. No two persons have either eyes or intellects alike; the subject might be very easy to one and most difficult to another. And thus it is in every branch of natural history: one man pursues his study with vigour and success, and twenty others retire almost on the threshold. In this field a collection consisting of ten well-filled drawers has revealed all the facts, and all that the author has done is to collect and arrange them; many yet remain to be deciphered, for the want of additional materials for their elucidation, and a few appear still very far from being correctly understood.

In accordance with the views respecting the variation of the shells in the genus Nassa, expressed in a paper read before the Literary and Philosophical Society, it is proposed to give an account of the fossils contained in this genus also.

The fossil as well as the recent shells have only been considered from one point of view, viz., that of their being separate and distinct species, and all the varieties must of necessity belong to one or other of these species. There are so many incongruities in the works of the most famous authors, with regard to the value of the characters said to constitute specific differences, that many of the shells quoted as varieties are much more distinct from each other than others quoted as species. On the

ccontrary many of the shells figured and quoted as the species of this or that author are so widely different, that we are at a loss to know how the learned author has arrived at such erroneous conclusions.

Neither system nor classification exists beyond the fancied resemblances derived from a false foundation. Classification should depend upon an intimate acquaintance with the law of affinity; it is utterly impossible for any one to assign to any set of shells their proper place in the system without first ascertaining their relationship with each other, as well as all those immediately connected with them. The fossil shells are closely allied to the recent, and have smooth, costate and cancellate forms among them, similar to the shells now living in the ocean; and if we may judge by such shells as the *N. reticosa*, J. Sow, there was quite as much variation existing among them in former years as there is now. It is absolutely necessary to know that the shells are extremely variable objects, and are by no means confined to the definite limits of the species maker. A cancellated shell is not necessarily a species in virtue of its cancellation, neither is a smooth variety to be considered distinct because of its smoothness; the one may be only a variety of the other, nor does the degree of sculpturing—that is, its fineness or coarseness—afford any additional evidence in its favour; many of the shells of the same species are well known to vary in these characters.

It will be seen by any person who will examine the subject, and who is accustomed to weigh evidence, that nearly the whole of the known fossil shells belonging to this genus are intermediate in their character, and consequently they can only be considered varieties. Many groups among the recent shells are very similar in their

ever-varying characters, and are entirely devoid of anything like fixity. The reticulated shells, such as *N. sequijorensis*, A. Ad., *N. marginulata*, Lam., not Reeve, *N. ravida*, A. Ad., &c., are all so interchangeable, that it is impossible to say where one begins and the others end. The train of shells combining the characters of two species are very numerous, and those exhibiting the combined characters of three, or even four supposed species, occur. Variation in every direction is here the rule, and not the exception.

It is quite time we opened our eyes to the fact that if we attempt any arangement of these shells on the principle we have hitherto adopted, it will result in an utter failure. The *N. cuvierii*, Payr, belongs to no less than five different sub-genera of Adams, represented by so many of its varieties.

In consequence of the variety of form, colour, coronation, ribbing, cancellation, and almost every other variation to be found in shells generally, this genus has been selected for the purpose of examining into the subject of the variation of species. I much question if another group of shells could have been chosen possessing so many advantages, of such varied characters, and so well adapted for the purpose, as this is. The gradations are marked and easily traceable, showing a progressive development of character from one supposed species to another. The degrees of coronation, from the smooth shells to the utmost development of coronation, can be counted from the appearance of one tubercle on the edge of the sutural canal to the complete coronation ornamenting the whole of the whorls. A similar series of observations, with regard to the ribs, is observed to take place from the simple elongation of the tubercles below the sutures, through every stage of development,

until we reach the full, clear and well defined ribs. A third series of examples are equally well defined, and show us the whole process, from a single sulcation through the series of crossgrooves forming the course or fine cancellation of the shell. Another character, viz., the callous of the columella is seen to vary from the thinest possible film, scarcely perceptible without the aid of a magnifying glass, to the thick, round button-like callosity, covering the whole front of the shell, and sometimes enveloping many of the upper whorls. The rugosity and the folds are equally liable to variation, and no reliance can be placed on them. The sutural canal is either open or closed in shells of the same species; and again all the intermediate stages can be easily traced. As to the colour externally, or the banding internally, there is no difficulty in determining its extreme variation. Two shells are before me; the one is a very dark purple, and the other is pure white, yet neither of these varieties are mentioned in describing the species. The shell is described by Reeve as of an olive colour, freckled with bluish white, although a specimen of this description does not occur in the Bay of Alexandria. *N. gibbosula*, Linn, the dark variety is found at one end of the bay and the light variety at the other; the shells found at the intermediate stations are mostly drab or light brown.

Is it absolutely necessary that the mass of information outside the pale of our works on conchology should be excluded. The only reason that can be assigned for such a proceeding is, we do not know how to deal with these materials. The sooner this extra knowledge is made to form a part and parcel of the subject matter of our book teachings the better. We have men in every department of conchological science species making,

not because they believe the shells are definite and distinct, but because nobody knows what a species is. A slight shade of colour, an accident, a slight difference in form, or even a coat of enamel, may serve to make species; some of which are so contemptible that I should think their authors feel ashamed every time they look upon them. We talk of classification, and at the same time endeavour to separate the materials upon which it should be based as far from each other as possible. All systematic knowledge is or ought to be based on an intimate acquaintance with the close alliances existing between both genera in the generic divisions, and species and varieties in the specific divisions; but the mode adopted is to show how distinct in every character they are. The present system of classification is erroneous, and however much the scientist may try to bolster it up, it must eventually give place to a more correct view; a much more expansive system is absolutely necessary, and it is time this old cramped up system should undergo an entire change. The information obtained by a study of this large series of varieties is of a certain and definite kind; as a natural consequence it is much more complete in some parts of the collection than in others, but the whole tendency is in favour of endless variation. It would be very difficult to substitute anything else. So clearly are the whole of the facts connected with this conclusion presented to our senses, that it is utterly impossible to mistake their meaning.

The *N. crossei*, Mayer, is a cancellated variety of the *N. cuneata*, Mayer, and the *N. ameliana*, Mayer, connects the *N. reticosa*, J. Sow, variety *rugosa*, with the *N. limata*, Chem. *N. angulata*, Brocchi, is a variety of the *N. gruneri*, Dunker, *N. tuburifera*, Mayer, is *N. mutabilis*, var. *Brocchi Subapp. Fossils*, Pl. 4 f, 18 a. & b., and two

other varieties are the *N. bicallosa*, Smith, and the *N. glabella*, Marrat. The *N. coronata*, Linn., *N. kieneri*, Anton, and the *N. marmorata*, A. Ad., are all varieties of the variable *N. mutabilis*, Linn.

A little knowledge is a dangerous thing. If these fossil conchologists had studied the variation of the recent shells, it is quite certain that nine-tenths of these described species would never have appeared either on paper, or been heard of by description. The folly of such a proceeding must have presented itself before their understanding and knowledge had been blinded to the act.

The *Nassa conglobata*, Brocchi, *gibba*, Roissy, *mutabilis*, Linn., and several other of the smooth and transversely sulcate forms, are simply varieties of such shells as the *N. clathrata*, Born., *verrucosa*, Gmel, &c., that is, if we allow that changes have taken place among these varieties, similar to those of much more frequent occurrence are known to do. Intermediate stages, such as *N. limata*, Chem., *prismatica*, Brocchi, *denticulata*, A. Ad., and many other varieties approximating in form, all appear to point in this direction, and probably would yield an unbroken line of affinity, if carefully studied. The *N. glans*, Linn., *N. reticosa* and *N. papillosa* are the first, the smooth, second the reticulated, and third the papillous varieties of one and the same shell. There are numerous varieties of each, and two shells now ranking as species, viz., *N. seminodosa*, A. Ad., and *N. hirta*, Kien., are both varieties of the last-named shell.

N. hispida, A. Ad., is surrounded by a large number of very closely connected varieties. The *N. conoidalis*, Desh., the Australian variety of the *N. sordida*, A. Ad., &c., my specimens of the *N. gruneri*, Dkr., were selected from a fine series of varieties of the *N. hispida*, and they agree better with the figure and description of

Philippi than any other shells I have seen under that name. The *N. keeni*, Marr., is a little more volute shaped than most of the others, the *N. albescens*, Dkr., has smaller granules than the allied forms, and the *N. nivosa*, Marr., is of a snow white colour, and the lines of rib-like granules are distinctly seen. The callous matter is extremely variable in thickness as well as its spreading, and a specimen selected from a number of varieties of *N. perlata*, Meuschen, is very closely related in its external structure to the *N. hispida*, A. Ad.; the *N. lirella*, Beck, and the *N. pauperata*, Lam., come into this category. It is very probable that the several variations of form and sculpture of the *N. clathrata*, Born, and the *N. verrucosa*, Gmel, and the *N. corrugata*, A. Ad., may all culminate in and be derived from the *N. reticosa*, J. Sow.

The fossil shells in this group present quite as much variation among the species as do the recent, and there is no apparent deviation from the plan upon which they were modelled. The smooth or simplest form is seen to pass into every other grade of variation; and every connecting link can be easily traced until we reach the most elaborate and complex sculpture. In this respect there is no difference in the plan observable in the recent shells. It is between these two points, viz., the smooth and the papillose, that all the variation lies. Form and colour are terms so vague in this genus that it is impossible to attach any value to them, not a single shell in the whole series can be said to be permanent in either of these supposed characters. Almost every species of the old authors presents more or less variation of the whole of the characters used for the purpose of determining species; and the varieties described under given names have to be selected from numerous closely allied forms.

You will be fortunate indeed if your shell is found to agree with the authors figure and description. When Alexander Agissiz obtained large numbers of what had been considered species among the Echinoderms, he was surprised to find the characters used for their distinction were so variable that it became impossible to employ them any longer. At least two-thirds of the shells given in Reeves "Conchologia Iconica," under the generic heads of Cyprœa, Conus, Natica, and most of the other genera containing large numbers of species, can be easily shown to be simply varieties. In whatever direction we turn a similar series of varieties spring up in our path. Among the minerals, Thompsonite in the family Zeolites has the following varieties, all of which have been classed as species, Mesole, Faroelite, Scoulerite, Chalilite, Ozarkite, Karphostilbite, and Comptonite; and a further search must add considerably to this number, so that conchology does not stand alone in the variable character of its materials, nor is this genus the only one in which the subject of variation may be studied. It is said the generic and sub-generic names were employed for the convenience of the student; if so, how does it happen that we have genera which should be distinct in other genera (Conus is an instance) also distinct? We all know the genus Conus, and I believe such a thing as a mistake in any of the shells belonging to it could scarcely occur. If we wish to preserve the science of Conchology, and expect to attain to a knowledge of it beyond that of our predecessors, we will not be content to stop short when we have acquired all the facts they had collected together; our knowledge will do little more than commence at the points at which they left off. To obtain more facts, and follow the subject much further towards its ultimatum, requires a much more careful

study, and on materials differing from those already known. Such is the study of variation. To those persons who are unacquainted with the materials thus brought to bear upon the subject, the whole of the new material will appear strange and incomprehensible. They cannot understand the innumerable facts that are constantly being developed, nor the inductive reasoning that is constantly being forced upon the mind of the student engaged in this advanced work. An entirely new field is opened for our investigation, and an entirely new set of objects are displayed before our wondering gaze. With such a marvellous set of ever varying shells thus brought together, the first impression produced upon the mind of the examiner is, a single species in an endless variety of forms. After years of study this impression, instead of being dissipated, is only strengthened; and, the more the materials increase, the more certainty of the truth first suggested remains as a thorough conviction. At first many of the shells stand out boldly, and appear to represent something distinct, but after a time the varieties above and below them so connect them with allied forms, as to completely sink all attempts at future identity. The shades of difference are so numerous and small, that it is almost impossible to say to which of these the original description or figure applied.

The study of the variation of species has revealed a number of facts that could not have been discovered by any other means. Without these series of varieties, it has been found to be impossible to arrive at correct conclusions with regard to what are termed species.

Suppose a person to be possessed of a large number of varieties of any of the common shells, such as *N. incrassata*, Mull., of which there are forty in a drawer before me, he will be enabled to detect the fossil shells

coming within the range of this variable species, and he will find that many shells figured and described as species, are simply varieties. Many of the recent shells are so intimately connected with the fossils, and are found to form so essential a part of the whole group, that the study of the genus would be very defective without them. A person engaged in the study of varieties, must of necessity pass beyond the bounds of the student of species; in fact, in many instances the amount of difference between the former and the latter is from ten to one hundred varieties of each species.

This large amount of additional information must have a beneficial effect, and one that will enable us to form much more accurate views regarding classification, than those based upon a simple knowledge of species.

Looking over the figures of the fossil shells proposed as species, it is surprising to see how few of them appear to present anything like distinctive differences. As a rule, the form and sculpture at once suggests the position to which they should be assigned in the scale of affinity, and if we compare them with the recent varieties, they seem to drop naturally into their places, as simple variations of common and well known shells. It is not absolutely imperative that two shells, the one being a fossil and the other being recent, should be of different species, the *Ancilla (Anaulax) buccinoides*, Lam., is identical with the *A. montrouzieri*, Sow.; the *N. maculata*, A. Ad., is the *N. labiosa*, J. Sow.; and the *N. granulata* and *monensis* are varieties of the *N. incrassata*, Mull.; *N. spectabilis*, Nyst., *blesensis*, *secticostata*, *turricula*, and *vulgatissima*, Mayer, are all varieties of the *N. incrassata*, Mull., and the *N. amelianum* and *vindobonense*, Mayer are varieties of the *N. limata*, Chem.

As almost every line of divergence in the shells com-

posing this genus seem to culminate in one or other of the multifarious varieties of the shells classified under the general head of *N. reticosa,* J. Sowerby, we may infer that they have originated in this species. In the first place the direct order of descent from the genus Buccinum appears to pass through this series, and to reappear in many of the smaller forms. It is only reasonable to suppose that the older species would be the source from which the newer shells were derived, and the lines of projection would be found to assimilate with specimens belonging to the parent stock. The genus Nassa was separated from the genus Buccinum by Lamarck, and like all other divisions it is very questionable if the student has not lost much more than he has gained by such a proceeding. In many cases the lines of affinity have been severed, and a large amount of confusion has resulted from these injudicious proceedings. Genera about which a mistake could scarcely be made, have been subdivided into others, which served no useful purpose.

Everything connected with species making is arbitrary and entirely at the will or caprice of the author. The shells comprising the species, *N. reticosa,* J. Sow., in Wood's "Craig Fossils," are generally admitted to constitute but one species; but the *Nassa glans,* Linn., which I believe to be only a smooth variety of the fossil shell, is divided into the *N. suturalis,* Lam., a simple coronated variety, with every intermediate stage of coronation from one to the other. *N. intermedia,* Dunk., from its supposed intermediate character; the shell figured in Reeve's, "Con. Icon.," pl. 2, f. 11, a—b., as a variety of *N. suturalis,* Lam., although the author says that the sutural nodules are almost obsolete, in which case it should be *N. glans,* Linn, are all more closely allied

forms than the fossils. Passing from these to the narrow forms, such as the *N. graphitera*, Beck., and the *N. gaudiosa*, Hinds., we find ourselves led by a series of gradations into the *N. cuvierii*, Payr. In the series of varieties last enumerated, the variation is simply confined to form and to the amount of coronation at the sutures; but in the fossil shells we have, in addition to these characters, a much more extended variation of form, a marked alteration of external sculpture, and, in every way, a greater variation throughout the series than is to be found in the recent shells which are designated species. Many of the figures quoted as synonymes of species are either very distantly related as varieties, or at least they are much more distinct than shells standing under the head of distinct species; so that a variety of one author is greater than a species of another.

ON THE INTER-GLACIAL AGE OF THE CAVE-MAMMALIA;

The Apparently Sudden Introduction of Man; the Mental Capacity of the Cave-Men of France; and the Shortness of the time which has elapsed since the close of the last Glacial Period.

BY DANIEL MACKINTOSH, F.G.S.

THE author commenced by stating that his paper was intended to be more provisional and suggestive than final. The recent tendency of opinion in Post-tertiary geology was evidently to throw the early history of Man further back, and to bring Glacial events nearer to our own day. Among Scotch geologists (as he had lately learned from Dr. James Geikie) there was a strong tendency to bring down the close of the last Glacial period to Neolithic times; while in both Scotland and England there was a tendency to make the Palæolithic period at least partly Inter-glacial, if not Pre-glacial. Professor Boyd Dawkins commenced with regarding all the Cave *Mammalia* as Post-glacial. Lately he had expressed his belief that the Mammoth made its appearance in Pre-glacial times. The author then stated his reasons for believing that between the two glacial submergences there was a dry land period, during which great numbers of animals and (in some districts) men were compelled to take refuge in caves, by causes not yet fully understood; and that, dead or alive, they were covered by the pell-mell deposit formerly called *diluvium*, which had been found filling many caves up to the roof, and which, in England and Wales (as the author believed) was an underground extension of the upper Boulder-clay. He

explained his reasons for thinking that, in the Cefn and Pont-Newydd caves (near St. Asaph) the "diluvium" could not be a re-deposit of the upper Boulder-clay by a fresh-water stream, because the small surface-area above the caves could not have supplied a stream of any considerable size. This surface-area could not have changed its configuration since the deposition of the upper Boulder-clay, because it is still more or less covered by that clay. The author likewise described the Kirkdale cave, of East Yorkshire, in which a Shapfell granite boulder was found lying on the surface of the "diluvium" which covered up the *Mammalian* remains. The author believed that the stone implements associated with the bones of the Cave-men of France rendered it probable that these Cave-men were approximately contemporaneous with the flint-folk of the Valley of the Somme, who lived during the deposition of a fluvio-marine gravel which (as shown by Mr. Alfred Tylor and others) is almost everywhere covered with a deposit of Loess, which the author (Mr. Mackintosh) regarded as the equivalent of the upper Boulder-clay of the north of England. He contended that the Cave-men of France showed by their artistic skill (all circumstances considered) that they were far from being *mental* savages, whatever may have been their external condition. He could not regard external magnificence and luxury as in themselves indications of true or permanent civilization. The earliest human skull yet discovered (the Engis cave skull) might have been the skull of a philosopher, according to Professor Huxley. The Neanderthal skull had been proved to be an abnormity not entirely unrepresented at the present day in the British Islands.*

* Report of the Birmingham Meeting of the Brit. Association, 1865.

So far as Geological discovery had extended, it favoured the conclusion that man was suddenly introduced, and the author agreed with Mr. A. Russell Wallace (one of the founders of the theory of evolution) that the origin of man was an abnormal event.* The main part of Mr. Mackintosh's paper related to the shortness of the time which has elapsed since the close of the last Glacial period. It had been rendered almost certain that in Scotland glaciers descended to the sea-level in Neolithic times; and it could scarcely be doubted that such must likewise have been the case in the Lake District and North Wales. The extreme *freshness* of the traces of glacial action in the latter countries, especially in Cwm Llafar, where a good-sized brook had only made a channel two or three feet deep in glacial drift, was inconsistent with the idea of more than a very few thousand years having elapsed since the final disappearance of the ice. The extent to which rivers in Cheshire, Lancashire, and Cumberland had excavated channels in glacial drift since the elevation of the upper Boulder-clay above the sea-level might be easily overrated, because it could be proved from sections of the upper Boulder-clay that it was more a *wrapper* than a *leveller* of pre-existing inequalities.

The idea of the recent close of the last Glacial period had been strongly corroborated by late discoveries in North America. The Falls of Niagara, according to the late Mr. Belt and some of the American geological surveyors, had receded only three miles, at the rate of nearly three feet in a year, since the final filling up of the Pre-glacial channel of the river by the Boulder-clay, thus indicating a period of less than 6,000 years since

---

* Address, Glasgow. Brit. Association Meeting.

the close of the last Glacial submergence; and the late observations and calculations of Mr. Winchell have rendered it probable that the Mississippi Falls of St. Anthony have receded to an extent indicating a period of nearly equal duration.

The author then endeavoured to shew that the time required for the Post-glacial oscillations of the earth's surface, (so far as they can be proved to be Post-glacial, and not Inter-glacial or Pre-glacial), need not have been nearly so great as has often been supposed, more especially as these oscillations took place between a period of great instability, (as shewn by the Glacial submergences), and a recent period of repose. The author believed that the continuity and distinctness of outline of the raised beaches had been much exaggerated; and from what he knew of the rate of encroachment of the sea on the shores ot the Bristol Channel, he had no doubt that the raised beaches off the west coast of Scotland may have been carved out of jointed rocks (irrespective of the hardness of the rocks), in a comparatively brief period; while their frequent *transverse* horizontality indicated a somewhat sudden emergence, as if partly brought about by earthquakes. The author, in conclusion, noticed certain phenomena which might be regarded as inconsistent with the views he had been advocating, among others, the Lake-dwellings of Switzerland, in reference to which he remarked that the probable extension of the glaciers of the Alps in Neolithic times, might have been accompanied by a much more rapid deposition of mud in the Swiss lakes than has been the case during the last few thousand years.

ANALYSES OF ROCKS FROM THE 1300 FEET DEEP BORE-HOLE, AT BOOTLE.

BY J. CAMPBELL BROWN, D.Sc., F.C.S.

1. Hard Sandstone, composed of angular grains; taken from the Pebble beds at a depth of 700 feet from the surface.

2. Lower Bunter Sandstone, composed of rounded grains; taken at a depth of 1180 feet. Softer than No. 1.

3. Slightly Marly Sandstone, composed of granular or powdery particles; taken at a depth of 1280 feet.

Results of analysis expressed in parts per cent:—

	1.	2.	3.
Sand and insoluble matter	95·16	94·2	86·72
Alumina and Oxides of Iron	·86	1·94	2·66
Lime	1·15	1·08	4·74
Magnesia	·88	·36	·82
Carbonic Acid (in combination with Lime and Magnesia)..............	1·48	1·	4·3
Traces of other substances and loss	·52	1·47	·76
	100·	100·	100·

The lowest sample approaches in composition the Upper Permian; but there is no reason to believe that it really belongs to the Permian.

The first few gallons of water pumped from the bottom of the bore did not seem to be affected much by the difference in the composition of the rock.

The water near the surface is very hard, owing to local causes; the hardness is slightly less at the depth of 600 feet, and it is again as high at the depth of 1300 feet as it is near the surface.

The proportion of Common Salt increases slightly as we descend from 500 to 1300 feet.

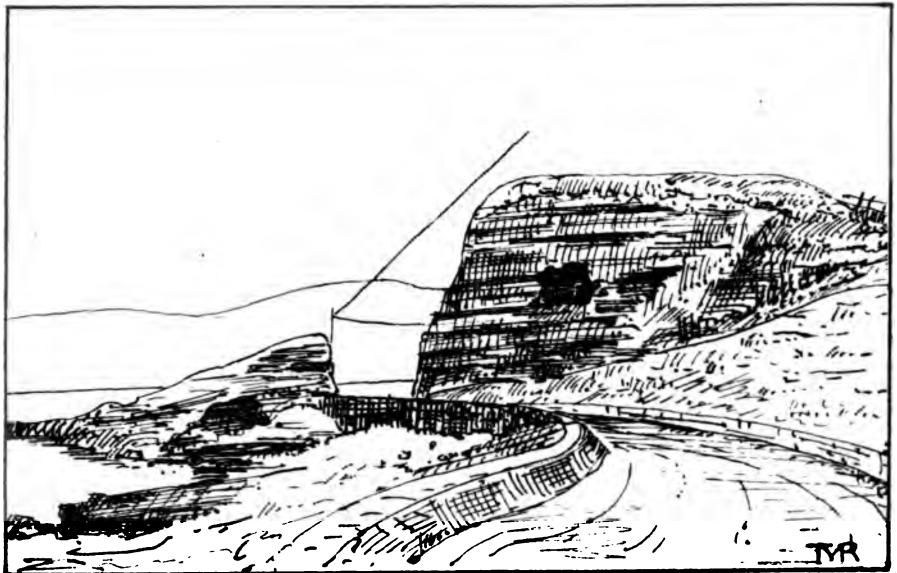
(We are indebted to the Water Committee of the Borough for permission to quote the above analyses.)

NOTES ON THE SCENERY AND GEOLOGY OF IRELAND.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

The connection existing between scenery and Geology has always been a very attractive subject to me. The following notes are principally the result of observations made during a summer holiday in 1878, and refer to the country from Belfast round the north of Ireland, and down the west coast as far south as Galway.

Landing at Belfast early in the morning, the first objects of interest to me were the raised beaches, containing flint implements, that margin the shore of Belfast Lough: a drive along the northern shore past Carrickfergus to Kilroot, gives one a very correct notion of the physical geology of the Lough. These Post-Glacial gravel beaches usually rest upon a purple-red Boulder-clay, not unlike the marine Boulder-clay about Liverpool. From descriptions I had read, I expected to find a much more persistent level obtained than what is actually the case. So far as my observations extended, these gravelly beaches are to be found at all levels between high water and 12 feet above it. I fear very much that the love of symmetry has misled many a geologist before now, and the persistent beaches at different well-defined levels, supposed to have been traced over a considerable extent of country, are often more "diagrammatic" than real. The Boulder-clay contains very large blocks of basalt and indurated chalk, intermixed with many flints. Large blocks of chalk lie on the shore, and exhibit signs of glaciation. It is quite evident that the Post-Glacial beaches are reconstructed from the pebbles of the Boulder-clay. At a point on the



– RED BAY –

shore approaching Carrickfergus, the Boulder-clay is seen to lie upon the Triassic Marls, thus further showing what I have formerly contended for, that the matrix of our Boulder-clay, which is of a similar nature, is principally derived from the New Red Marl.

An excursion along the south shore shows an extensive alluvial flat, increasing towards Holywood, near to which it is bordered by a low gravel bank eroded into a low cliff by the waves. As is usual in such cases, a stream occupies a position between this bank and the old margin of the Lough.

In a quarry by Cultra the eroded edges of the Silurian rocks are overlaid by a deposit of Drift containing some few pieces of red sandstone. The Drift is of a red colour and irregularly bedded, having the appearance of being sub-aërial waste.

Near Bangor, in Ballyhome Bay, is a very extensive cliff of sand and gravel, consisting of alternating beds, one thick bed situated near the base being composed of gravel and shingle. The beds are numerous, vary much in thickness, and have a general dip to the left as you face the cliff. I could find no shells. The surface was undulating, as is usual in Drift countries, and covered with grass.* A Post-Glacial beach, with shells about five feet above high water and resting upon the Silurian rocks, is to be seen at another point between the last section and the village of Bangor. The general appearance of this place—rocks, houses, walls, as well as the name—reminds one strongly of North Wales.

Between Bangor and Newtownards there is a good exposure of rounded, knobby rocks, well smoothed, but

* Mr. Joseph Wright, of Belfast, informs me that these sands and gravels are considered to be Post-Glacial.

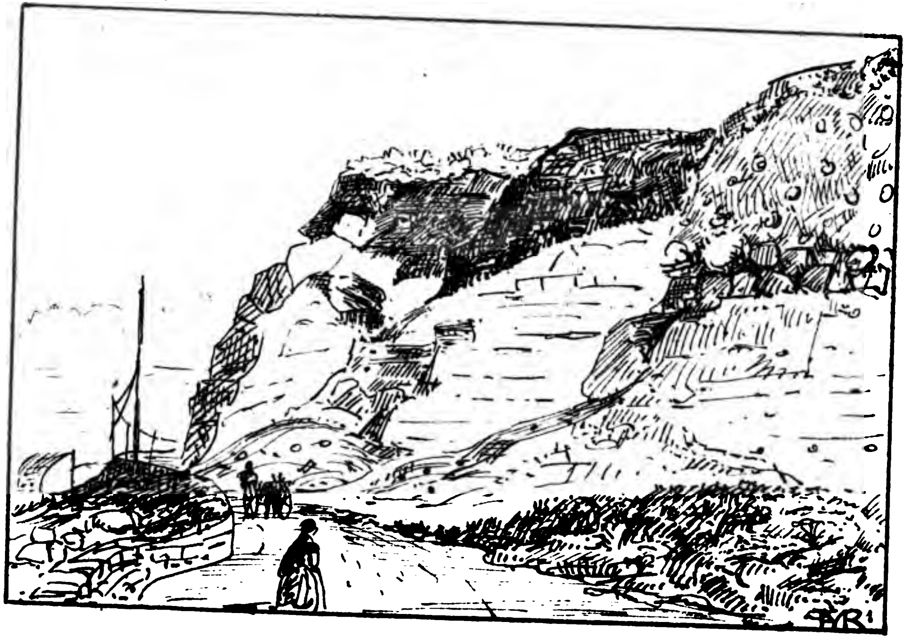
unstriated. Approaching the sandstone quarry at Newtownards is an exposure of Drift, in general appearance intermediate between moraine matter and our Drift. In this I detected a well-faced striated stone, of which I took a chipping. Further on a cutting in the road shewed a section of what appeared at first sight to be sand, but really proved to be a mass of basalt decomposed in situ, exactly as the stones of a similar nature in our Boulder-clay are found decomposed into a sand. This was covered by a rubbly Drift.

The Red Sandstone quarry at Newtownards was especially interesting to me. The stone is exactly like the Runcorn Keuper, and is pebbleless. This is a remarkable proof of the extended area over which the same conditions prevailed at this period, and is suggestive of facts in physical geology. The preservation of this small patch of secondary rock is highly instructive, and a further indication of all that Mr. Judd urges of the great destruction of secondary strata that has taken place in Great Britain and Ireland. There is another patch of Triassic strata that I am acquainted with, at Kingscourt, between Meath and Cavan, preserved by a trough fault.

The top of the rock is covered with a Drift about twenty feet thick, of a red-sandy nature, with a few included stones and flints. This Drift is also evidently largely reconstructed from the underlying material.

From Larne to Cushendall sections of a Post-Glacial raised beach are to be found along the coast, and flint implements washed out of it are to be picked up on the shore. The distinguishing feature of the geology of the district is the basalt overlying the chalk, and very picturesque sections are met with in the coast cliffs.

Near Ballygally Head is a gravel pit disclosing a very interesting section of Drift. The lower part of the section



– GLENARM –

is composed of current-bedded coarse sand and fine gravel; then follows a bed of sand, very regular, about four inches thick; above this is an irregular mixture of sand and clay, graduating into an unstratified arenaceous Boulder-clay. Capping the whole is a thin bed of surface detritus, on which is a covering of grass. In the sand and gravel fragments of shells were very common, among which were *Astarte elliptica* and *compressa*, *Leda pernula*, *Mytilus*, and *Natica*.* †

At Glenarm the junction of the basalt and underlying chalk is well exposed in a quarry by the road, and the Boulder-clay, a sort of grey Till, is also seen at another point, as shewn in the sketch reposing on the chalk. At Carron Point the basalt and chalk are well exhibited. Further along the coast we come upon exposures of Red Marl, and at Red Bay sand dunes are to be seen. Being so familiar with them at Crosby, I instantly looked round to trace their origin, and found it in the New Red Conglomerates and Old Red Sandstone. The New Red Conglomerates contain mostly boulders of quartzite and a schistise granite. Sea caves are also to be seen half-way up the cliffs (see sketch). At Cushendall, on the coast, are what appear to be Old Red Sandstone rocks. This is a very picturesque spot. The most striking feature in the landscape to a stranger, is the abundance and luxurious growth of fuchsias.

From Cushendall to the Giant's Causeway.—At Glen Dun, just past the bridge, are exposures of angular Drift lying on the mountain side; in one case this was rudely stratified. At the top of the road there is a thin covering

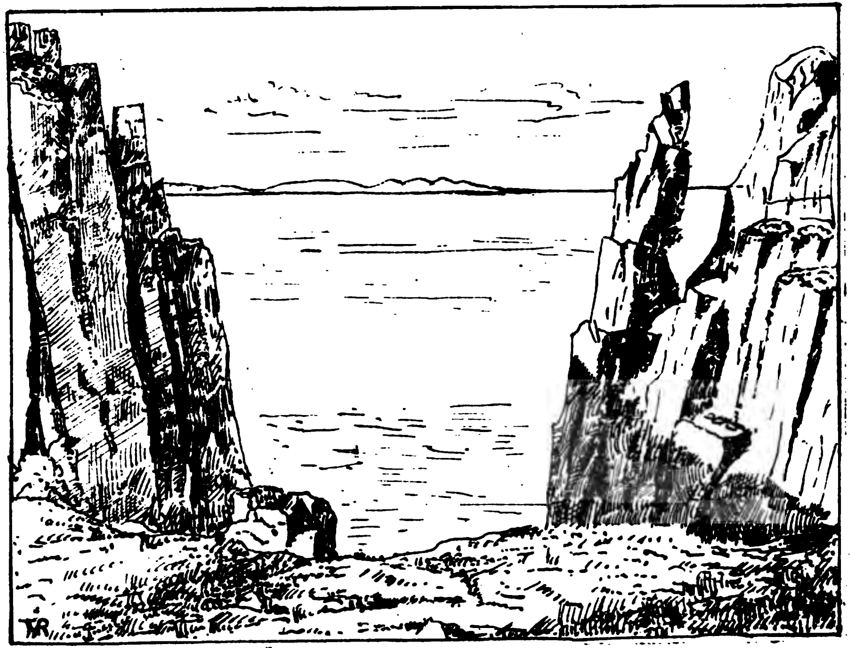
* I am indebted to Mr. R. D. Darbishire for these determinations.

† Mr. Joseph Wright tells me he has taken 25 species of Foraminifera from these gravels. Dr. Grainger gives in the Report of British Assoc., Belfast, 1874, a list of shells frem those gravels at apparently the same same place, called by him "Ballyrudder," and also states that he found a mammoth tooth in them.

similar Drift lying upon broken gneissic rock. On the moor above there also appears to be a thin covering of similar Drift, and indeed this character of Drift is also commonly met with among the mountains in Great Britain.

Just as the road begins to fall towards Ballycastle is a singular lakelet, which only contains water during heavy rains. My attention was attracted to it by there being apparently no outlet, while a stream of water of considerable proportions was running into it. The driver of my "outside car" informed me that it disappeared through a hole in the bottom, and that in dry weather only a pool of water remained about two yards across. At different levels were to be seen beach marks; first black mud, next a gravel beach above it, and a beach above that strewn with boulders, forming perfect zones at well-marked levels surrounding the pool of water, which was then about 150 yards in diameter. The surface of the country was bog. I imagine this must be a swallow-hole in the chalk—though I could see no signs of chalk about—as the pool occurs just on the junction of the gneiss and chalk, as nearly as I could judge, according to Hull's geological map of Ireland. The swallow-hole not being equal to taking storm water, when storms occurred a lakelet formed. It struck me as a singular phenomenon, and it is certainly the first instance I have seen of a lake with the "bottom knocked out!"

At Fairhead is to be seen a grand example of glaciation. The basaltic rocks are there, over a large area, ground into rounded forms. It is, in fact, one great *roche moutonné*. I examined it closely, but could find no groovings or striations, but I do not think it possible the phenomenon could result from field-ice, for every channel between the knolls was as perfectly smoothed as the



-FAIRHEAD-

convexities. It appeared to me that only the passage of an immense sheet of land ice could account for such a surface form. I confess that, after all the extravagances of the Glacialists of late, I began to feel rather "cool" towards the Glacial Period; but here was indubitable evidence of the action of some great moving force.

A peep over the cliffs at Fairhead well repays the lover of the picturesque, the artist as well as the geologist. I sometimes think that while paying such close attention to the frame-work, the anatomy, so to speak, of this world of ours, we neglect the other side of Nature —beauty, form and effect. Sketch-book in hand, I try to preserve myself from this dry and arid feeling; but a look over the cliffs at Fairhead, a perfectly vertical wall of rock hundreds of feet high, the sloping *talus* below appearing almost level land through being directly under the eye, and the opposite coast of the Island of Islay high up on the horizon, the most unemotional investigator must be for the moment drawn out of himself by the unexpected grandeur of the scene. Not less grand, and more beautiful, is the view from Fairhead over Murlough Bay.

THE GIANT'S CAUSEWAY TO PORT RUSH.—So much has been said and written about the Giant's Causeway, that an exaggerated notion of its geological importance prevails. Having been frequently warned by people I met on my journey that I should be disappointed, of course I was not. I detest show places, so after making a couple of sketches of scenery that would appear more remarkable were it not so much talked of, I was not sorry to go on to Port Rush. There is much grander scenery in Ireland than the Giant's Causeway, and it is only the remarkable regularity of the columnar structure of one of the beds of basalt that makes it an object of curiosity.

Port Rush is a pleasant place to spend a day or two at. To the eastward is a long sweep of sandy shore terminating in a dark promontory of basalt. On the shore to the westward are the remarkable Lias rocks, converted into hornstone, formerly the subject of so much controversy between the Wernerians and Huttonians; and also the raised Post-Glacial beach mentioned in Portlock's "Geology of Londonderry." The sea has quarried out the altered Lias rocks, leaving large lumps, that on a sketch look more like wagons than anything else. The chalk cliffs and caves a few miles eastward of Port Rush are, I believe, well worth a visit, which should be done in a boat. There are also good sections of the chalk to be seen from the road, between Dunluce Castle and Port Rush, with sections of basalt filling up a valley in the chalk.

Port Rush to Derry and Moville.—The Railway passes under the Magilligan headland, where you often see the basalt capping the chalk. This headland is a striking object from the opposite side of Lough Foyle. Taking the steamer from Derry to Moville, we get a good view of very pleasing scenery, the herbage coming down to the water's edge. The green fields of the shore, and the sunshine, rain and rainbow effects, on the water, were very beautiful. Near Moville I stayed a few days with a friend, and joined Dr. Wm. King in several geological and antiquarian excursions.

The rocks of Donegal, between Loughs Foyle and Swilly, are mostly gneiss and schist, with occasional beds of limestone more or less crystalline. In one quarry we examined between Red Castle and Moville, the limestone was very carbonaceous and much crushed and crumpled. No fossils were to be found but patches of carbon and graphite, as if the skin of an animal or the

soft parts had become carbonised. Near this I discovered some glacial striations in a smoothed trough of schistose rocks, having a bearing magnetic E. and W.

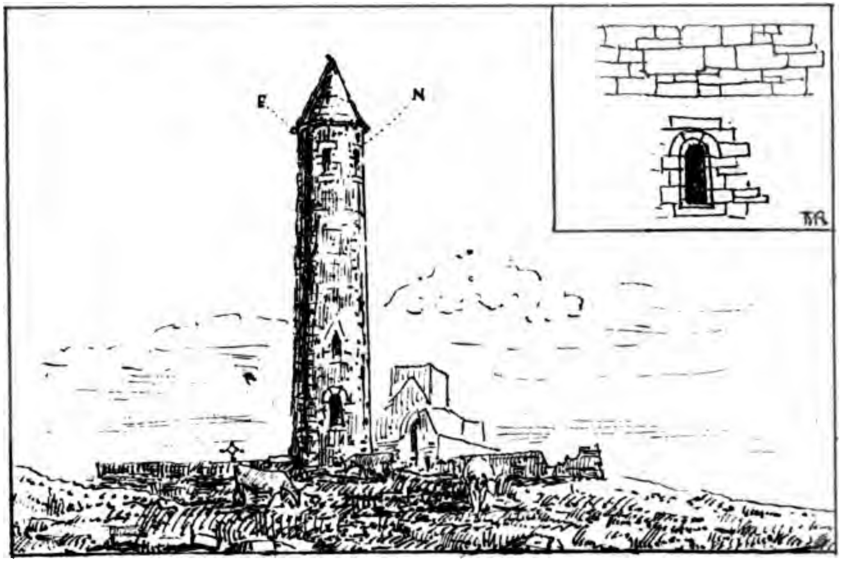
At Carramore the antiquary will be interested in the striking stone crosses to be seen in what is now a field. One that I sketched stood 12 feet out of the ground, and was cut out of one piece of flaggy sandstone; but perhaps the most remarkable object in this ancient burial place, was a rude stone lying on the ground, with a Latin cross upon it, incised, the arms representing truly the several points of the compass, shewing that the stone had not been moved since the cross was worked on it; close to it in the same block was an eliptical hole, 11 inches by 8 inches, probably for holy water.

On this journey we passed a bog where stumps of trees were exposed; on examination I found them to be rooted in the clay below. They were both of oak and pine. It is curious how they bleach white with the weather. The pine was being cut up for firewood. Its timber when freshly cut was as clear and sound as a bell, of a reddish tint and very resinous whereas the oak appeared decayed.

Near Moville there is a good development of Drift by the banks of a stream. It is hard, and looks like a conglomerate, standing with a vertical face about 20 feet high, where the stream at a bend has cut into it. There had recently been a fall of a portion by undermining, but such was the tenacity of the mass that the upper part bridged it over, forming a cavern, the stream meanwhile being engaged in washing the fallen mass of Drift away. I could find no shells in it. A thin covering of Drift lies usually on the rocks, always partaking of their nature. Between Moville and Carramore I observed

some glaciated schistose rocks, with groovings 20° W. of N., or at right angles to those before described. Along the shore of Lough Foyle are to be picked up among the loose stones, very good examples of plicated schist.

Before taking leave of the remarkable district we have just rapidly traversed, it will be instructive to consider what geological impression it leaves on the mind. The preservation of the Chalk, Lias, and Triassic beds which occur under the capping of basalt, is the most noticeable thing that strikes the geological observer. Casting the eye over Professor Hull's "Geological Map of Ireland," we see that nowhere is the Chalk or Lias to be found excepting on the margin of the basalt, and if we omit the little patch of Trias in Meath and Cavan, the same may be averred of the New Red Sandstone. The Oolite, according to Portlock, is represented by a patch under the the Chalk near Magilligan headland, from 40 to 50 feet thick, and not having a great horizontal extension. Only less remarkable than the absence of these strata, excepting at the outcrop of the plateau of Miocene dolorite, is the enormous amount of denudation which has occurred since the Miocene lavas were poured over the Cretaceous strata. This is to be seen in every valley opening on to the coast line, the horizontal sheet of basalt being severed by the actual removal of the strata which formerly filled up the space now occupied by the valley, which is frequently cut down through the Chalk to the strata below. All this work must have been effected since late Tertiary times. It would be an improbability, amounting almost to the ridiculous, to suppose that the lavas were just poured over the whole of the Chalk and nowhere else. Every fact points to the conclusion that enormous areas of strata from the Triassic upwards, have been removed by denudation since Miocene times. A study of



– DEVENISH –

Mr. Judd's admirable third paper on the* "Secondary Rocks of Scotland," will not fail to forcibly impress one in this direction. The isolated patches of Secondary rocks he has so assiduously sought and found, and the geology he so graphically describes, must, I think, lead to the view advocated by him, that these rocks are, so to speak, but the torn pages of the book of nature, of which the missing portions, once continuous, have been removed by denudation. What a vista of geological time does not this unfold?

ENNISKILLEN.—By the railway in Tyrone, on the way to Enniskillen, there appears to be a great development of limestone boulder Drift, extensive and deep, cut into knolls by rain and river action. It has certainly been much denuded. There is a similar Drift by Lough Erne.

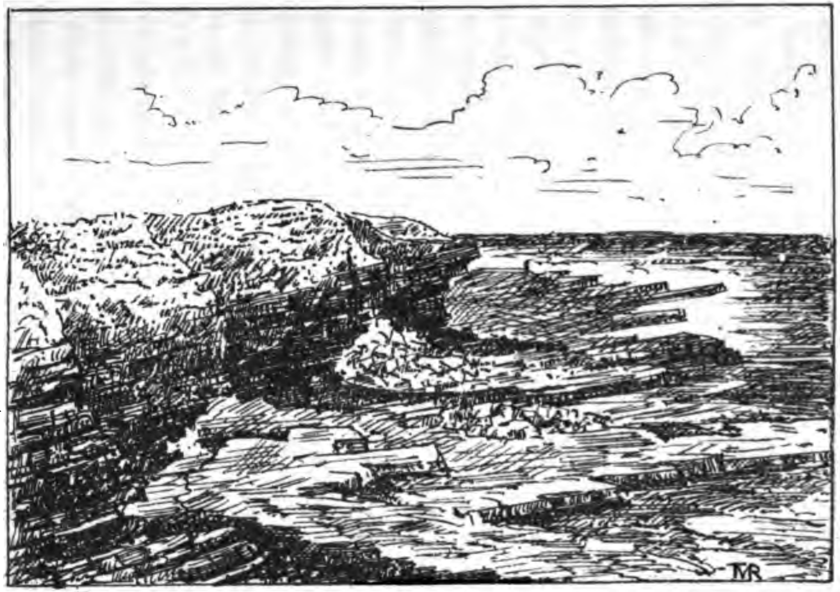
On the island of Devenish is the most perfectly constructed Round Tower I have seen in Ireland. The joints and beds are most beautifully fitted together. The stone is a sandstone, probably Carboniferous. The boatman informed me that there is a quarry of similar stone about two miles up the lake. The top of the cone-shaped roof had been forced off by a tree growing out of it, and about five feet had to be rebuilt. The jambs of the doorway shew the most perfect workmanship of the kind I have seen. It is remarkable that the church close to is all of Mountain Limestone excepting one niche, which is of sandstone similar to the tower. The masonry of the tower is comparatively little weathered. Most of the stones are on their natural bed, but some appear to be set vertical to the bed. The windows at the top are nearly true N. S. E. and W., but the door is not to a definite point of the compass, being a little to one side of E. (see sketch). The boatman informed me he had

* Quarterly Journal of the Geological Society, August, 1878.

gone on sounding expeditions on Lough Erne, and that no part of it was more than 100 feet deep, the average being about 60 feet; the bottom under the mud was blue clay. This lough winds about more like a river than a lake.

Bundoran.—Here are to be seen two things—very remarkable cliffs of Carboniferous Limestone rocks, and not less remarkable bathing! These cliffs, though not at all lofty, are, from their rugged outlines, very grand. The sea quarries out large blocks; one I saw was about the size of a large cottage. The grandeur of outline is due to the regularity of the bedding and jointing, the rectangularity of the jointing being repeated from the largest to the smallest scale, so that in places the rock is divided into cubes of 3 inches. The view of the escarpment mountains of Carboniferous Limestone forming the background, the accidentally pretty grouping of the houses of the town, and the foreground of bold grey rock with brilliant orange seaweed on the shore, together form a picture not to be easily forgotten. Fossils are plentifully exposed on the shore rocks, but are not easy to detach perfect. I saw *Productus giganteus*, almost as large as my head. A boulder drift is to be seen all along the top of the cliffs. The cliffs to the west of the town are especially grand.

From Bundoran to Sligo we pass over a limestone plain, and have in view all the way the striking escarpment face of Benbulben. The top of this mountain is a tableland, 1,722 feet above sea level, on which there is about twenty-one acres of bog where turf is cut. The limestone beds are nearly horizontal, as seen from the road, and the tableland being bounded by a wall of rock finishing with a curved *talus* of remarkable regularity, renders this mountain a very conspicuous feature in the



- BUNDORAN . W.

scenery. Here and in the Burren, County Clare, is the only limestone scenery in Ireland of a mountainous character; the rest, although of vast extent, is a plain.

At Drumcliff is the base of a Round Tower of very rude workmanship, and also a very richly-carved Irish cross.

Sligo is remarkable as a commercial town lying in the midst of beautiful scenery. On one side of the river are the quays, with vessels lying to them; on the other, green fields and grassy slopes. Half-an-hour's rowing will take us up to Loch Gill, and among some of the most beautiful scenery in Ireland. On one side of this lake the Carboniferous Limestone is faulted against metamorphic schists. These schists constitute the mountain scenery of the lake, characterised by rounded outlines, strikingly different to Benbulben, which may be seen, in all its squareness, from the southern side of the lake. The lake itself appears to be wholly in the limestone. The mountain slopes, the shores and islands of the lake are beautifully wooded. The water, mirror-like, reflected clearly Nature's loveliness, which the Irish gnats seemed determined I should not transfer to paper!

From Sligo to Ballina we have the Ox Mountains on our left most of the way. On this journey we were accompanied in the car by a number of Irish butchers, who seemed on the most affectionately embracing terms. They laughed, they hooted, they shouted, and chaffed all passers-by, while occasionally caressing each other. The truth that "men are but children of a larger growth" was strongly impressed upon me. The morning was bright and sunny, and although the route is described as a "dreary drive," we did not find it so. There was a beautiful view, over Sligo Bay, of the mountains of Donegal, and all Nature seemed pleasant and beaming.

Large boulders were to be seen as we approached Ballina, apparently of granite which had been uncovered in the digging of turf, which apparently bottomed on Drift-clay.

From Ballina is a very nice excursion to Killala. On the way I examined a bog, with the same results as described in Donegal, excepting that I found, in addition to pine and oak, a birch branch. The pine trees bottomed on the Drift-clay. A very intelligent Scotch farmer I met at Sligo said he farmed land near Ballina, and had frequently taken pine timber out of the bog, sawn it up, and used it for building. He was very positive the pine was not Scotch fir, describing it as a species of red pine. The timber he considered was more durable than ordinary building timber. In a very old house in the neighbourhood it had been used, and is as sound now as ever. One trunk he sawed up was four feet in diameter at the butt and 36 feet long, "shaped like a round tower," which he described was the characteristic shape of the timber.* He had also found firkins of butter in the bog—a common occurrence, as may be seen on reference to Kinahan's recent "Geology of Ireland."

At Killala is a Round Tower built of limestone, the stones rude, irregular and open jointed. It has been patched up and repaired at the top. The four windows represent nearly the points of the compass; the door, as usual is a little to the side of a perpendicular from one of the windows, in this case being nearly S.W.

On the return we visited Moyne Abbey, an interest-

* The late Dr. Moore, of Glasnevin Botanical Gardens, Dublin, was very strongly of opinion that only *Pinus sylvestris*, or Scotch fir, occurs in the Irish bogs. Mr. More, another botanist of Dublin, also holds the same views, and informs me that the authority for the reported occurrence of cones of *Pinus pinaster* and *pinea* in the bogs is Sir William Wylde's "Catalogue of the Antiquities in the Royal Irish Academy," p. 199. "This is quoted in former editions of Babington's Manual, but has been omitted in the last."

ing ruin, with characteristic central square tower, of a type, so far as I know, peculiar to Ireland. We also paid a visit to Tom Molloy, a local celebrity, who carves in bog oak, and occupies a roadside tavern. Like many geniuses Tom is a singular man. He took me into what he calls his "studio," and there resting on his bed was a cleverly carved armchair, with the arms "articulated" in short joints which bent to the pressure of the arm. Unfortunately I applied too much weight and one arm gave way, the pieces scattering like beads over the floor. They had been threaded with a piece of string. There was really very little harm done, but Tom sorely disconcerted returned to his shop, resting his chin on his hand and his elbow on a beer barrel, with an expression of reproachful melancholy on his face. I felt very sorry, but he was now unapproachable, so all I could do was to take a lingering look at a figure carved in stone, which appeared more like a Hindoo god than anything else. The man evidently had talent but it wanted educating. It struck me that his representations of the human form preserved much of the characteristics of savage art. It appears as if in the life of the individual is the history of the life of the race—another fact for Darwin! Bidding good-bye to the statue of Dan O'Connell on the roof of Tom Molloy's residence, we drove on to Ballina.

From Ballina to Westport the railway shews limestone Drift until we reach Foxford, where there occur large boulders of granite, also gneiss in the Drift; this is a sure sign of the proximity of these rocks. Alternating patches of gravel Drift occur up to and on the margin of Lough Conn, which the railway skirts, and large blocks occur by the lake. At Manulla junction I examined a section of the Drift in the cutting. It is of black limestone. The stones are slightly scratched, not

planed or grooved. There were also some pieces of sandstone half quartzite, and some quartz pebbles. Bog, alternating with Drift getting of a reddish colour, are seen in the cuttings as we approach Westport.

Arriving at Westport we lost no time in getting down to Clew Bay, where we engaged the services of Mr. Wood, his boat, and his boy. This was really a delightful day. Clew Bay is full of islands of Drift, with instructive sections at every turn. These islands have been horizontally eroded by the water forming a beach and a cliff, in some cases, as in the island called the "Scotchman's Bonnet," extending all round. Some of the sections, as at Pigeon Point, shew an overlying, irregular mass of limestone conglomerate, formed by the cementing of the blocks of limestone by carbonate of lime. At one point this has been worn into caverns and fantastic shapes by the action of the waves. Many of the islands have a slope one side, usually landwards, and a cliff on the other. It is evident that they were all rounded in outline once and have been worn into cliff by the sea since. It appears that the beach, once formed, helps to protect the Drift from further denudation, as then it is only very high tides and gales that affect it.

We landed at Dorinch Island, the western face of which is cliff-like, 100 feet high, the face being furrowed in vertical grooves in a remarkable manner. This must partly result from the wash of the spray of the sea as well as from rain, but it is a proof of the consistency and firmness of the Drift that it assumes and preserves this form.

The Drift is mostly calcareous; there are large blocks of quartzite and some trappean rocks scattered about, but I could see none that were planed or grooved, though I examined many. The limestone blocks are

. THE BREAKWATER FROM DORINCH — T.R. —

worn into smooth, irregular shapes, and indifferently scratched. Most of the blocks are angular or subangular. Those on the shore were worn either quite smooth and oval or were subangular. The biggest stones were on the top of the ridge, so far as I could judge.

This island is connected with another by a very remarkable natural breakwater of pebbles, about 1½ miles long. A spur runs out on the southern side of the bay, and another extends towards it from the island, leaving a water passage between, about 300 feet wide and 100 deep. At the north end, the boatman informed me, there is a similar passage. Thus a natural harbour is formed in Clew Bay similar to that inside the breakwater at Plymouth. The sea must be very stormy here at times, as the boatman said when it blew a gale he could hear the breakers at his home 7 miles off.

This ridge must be continually altering and reconstructing, as on the inner side eastwards, it was, when I saw it, eaten into and worn quite steep like a cliff. As far as I could judge the biggest stones appeared to be at the top of the ridge. No doubt all the material has been derived from the Drift, probably some of it torn up from the bottom. The width of the ridge at the top was only about 10 feet, and its height about 8 feet above spring tide, as nearly as I could judge from the tide mark of seaweeds. The top is flat, and the section on each side a concave curve getting quicker towards the top.

This is a very remarkable physical phenomenon, and one well worth studying. It appeared to me to be due to the set of the tidal currents through the islands, modified from time to time by the wind. Like the Chesil Bank, the sea builds up its own barrier, and every storm piles up new materials to resist its own force, but the constant action of the tides mainly determines the

result. The waves are destructive as well as constructive. I think such a natural feature could not form in any but comparatively shallow water. The inrush of the tide through each water way being so restricted will keep them deep and clear. The breakwater is the resultant of a variety of forces; and, perhaps is more remarkable, though not so large as the Chesil Bank.

From Westport to Leenane we pass over a country of bog and boulders with occasional stumps of trees peeping out. At Errive there is a fine section of gravelly moraine Drift, where the river cuts through it, and fine glaciated rocks beyond. There is moraine Drift all down the river valley.

At Leenane there is a section of stratified boulder gravel Drift to the left just before reaching the hotel.

At Kylemore, by the lake, current-bedded boulder Drift is to be seen; beyond Letterfrack moraine clay.*

At Clifden there is a remarkable pebble breakwater at the entrance to the bay, of very considerable area, at the top partly covered with grass, and about 6 feet high above spring tides. The pebbles are very irregular and not much worn, being mostly of schistose rocks.

In the drive from Clifden to Galway there is nothing very noticeable from the car. At Glendalough, Hull says there is a terminal moraine in one of the side valleys. Recess is a very pretty place. At Oughterarde the river has cut a remarkable overhanging shelf of rock out of the limestone. The scenery of Connemara is very like parts of Scotland, but on a less scale.

At Galway I was hospitably entertained by Professor King, and we went a short geological excursion together to the Burren, in county Clare. The terraces of lime-

---

* The scenery has been so often described that, though beautiful, I have not ventured to again describe it.

stone as seen from the bay are striking. They are more numerous and regular, and extend to greater distances than any limestone terraces I have seen elsewhere. Landing at Ballyvaughan we ascended the Corkscrew Hill on the Lisdoonvarna Road. There the terraces can be seen to advantage, encircling the hills on either side of the valley. A large portion of the surface of these limestone steps is devoid of vegetation. The eye ranges along the valley over the Galway Bay to the opposite coast, and on a rounded hill at the mouth of the valley, set against the background of blue water, we see the upper part bare grey limestone, the lower slopes green with vegetation, and it *is* green here; the limit of growth being so defined a line, as to occasion a dispute as to whether it were not bounded with a wall; further examination proved it was not.

The best view of these extensive terraces is undoubtedly to be had in the Columkill Glen. One of the hills is so encircled with terraces as to give it the appearance of a pile of cakes of successively smaller diameter towards the summit. Mrs. King has christened it Cake Mountain! From the road towards the head of the Glen the curving of the terraces is well seen in perspective, as some of them are slightly below the eye. Geologically speaking, it is a grand country, and in its way one of the best things I have seen. Nor would the Burren, I think, altogether fail to kindle the enthusiasm of the artist. In some cases the lines of jointing can be seen from top to bottom of the mountain, as straight as a die, from the tufts of vegetation emphasising them. All the rain water disappears through the joints and fissures, and reappears as springs. The town of Ballyvaughan is supplied with water from three of these springs, conducted thence in iron pipes. Each spring is

a "holy well," and usually there exists a thorn close by, to which votive offerings of red cloth are tied by the pilgrims. It is the sort of country which to live in is to be superstitious; Nature in her aspects seems to make it so.*

I will not attempt to explain the way in which I conceive these terraces have originated, excepting to record my view that they are subaërial, though candour compels me to say that my friend Dr. King thinks differently. At all events, they clearly show one thing—enormous denudation. The terraces are nearly horizontal, but not quite, and follow the lines of bedding. The beds have evidently been continuous across these wide and extensive valleys.

At the entrance to Columkill Glen there is a ruin of a church, with a doorway constructed in the Cyclopean style of masonry. Unfortunately a ram occupying the field objected very strongly to our antiquarian researches, and a battle ensued lasting twenty minutes. The geological hammer eventually settled the dispute sufficiently for us to get away, but only one jamb of the doorway was sketched. Mr. "Butt" established "home-rule" in his field at the expense of a very sore head.

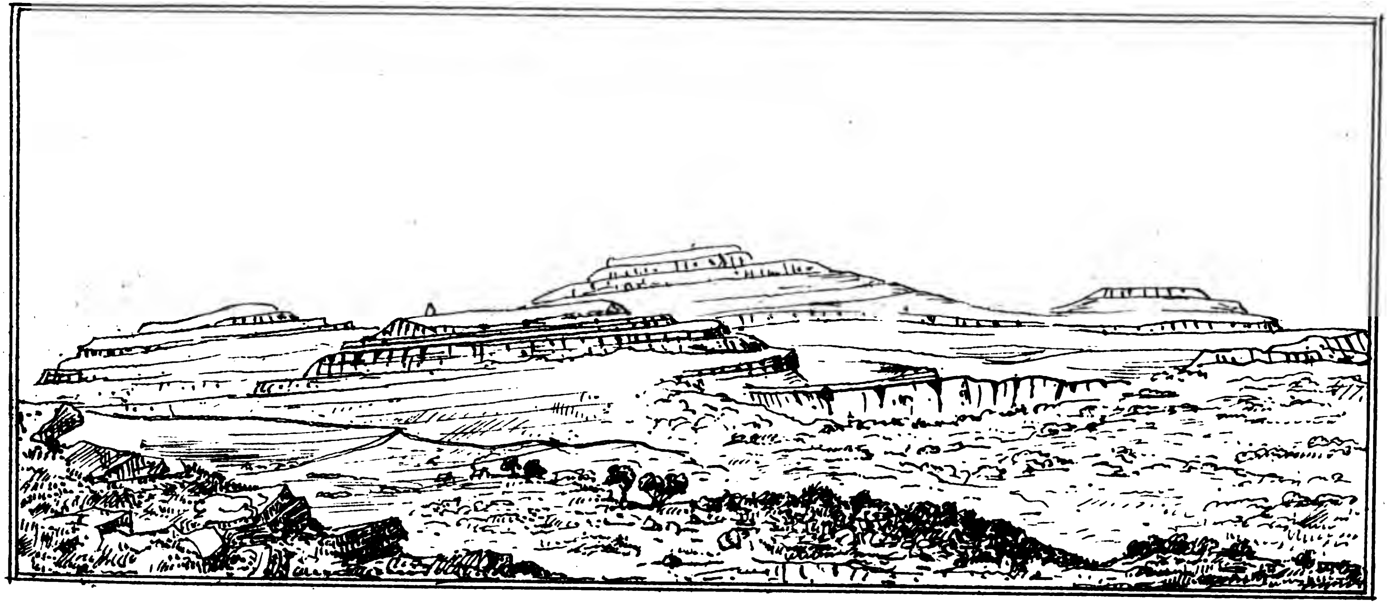
Corcomroe Abbey is a good specimen of transition from Norman to Early English, and possesses some specially Irish points worth noticing. †

I have now sketched the features of the country as they appeared to me while I rapidly passed through it; but as I devoted rather more time to the examination of the Drift about Galway, I will, before finishing, treat of it separately.

---

* An account of the Burren, by me, is shortly given in the "Science Gossip," January, 1879.

† A measured drawing of this Abbey, and also of the Round Tower at Kilmacduagh, were published in the "Architect," July 12th, 1879.



- THE BURREN - Aug^t 1878.

DRIFT OF GALWAY BAY.

At Blake Hill, about two miles west of Galway, a typical section of the Drift is to be seen. The whole hill is composed of a mass of calcareous detritus, extremely finely comminuted. It contains many boulders and large stones, the majority being limestone and the next in quantity granite. The sea has eaten into the originally rounded hill and made very fine cliff sections; and such is the compactness with which this calcareous cement has set, that the cliffs are vertical, and indeed in some places overhang. The face is studded with stones of all sizes, the larger ones apparently being near the top. On the surface of the top of the hill, now covered with pasture, are also to be seen large blocks, probably weathered out of the Drift. On the shore in front of the cliff there are many stones, and among them I noticed one of Moycullen granite that measured 14 ft. by 11 ft. 6 in., by 10 ft. outside measurement, containing about 1,600 cubic feet of stone, which at two tons to the cube yard would weigh about 80 tons. At one place on the shore are some limestone blocks of curiously contorted shapes, due to subaërial erosion; and Dr. King is of opinion they came from Lough Corrib, and were eroded before being deposited in the Drift.

The stones in the cliff are many of them scratched, but only "furtively." I saw none planed and grooved, such as we are accustomed to see in the marine Boulder-clay of Lancashire. Those on the shore had their scratches effaced. One limestone block on the shore measured 7 ft. 6 in., by 4 ft. 6 in., by 3 ft. 2 in. There is an island of Drift not far off, and Dr. King says it shows more traces of stratification than Blake Hill.

On the landward side of Blake Hill is a gravel pit containing strata of shingle, gravel and boulders, rounded

and occasionally slightly scratched. The lines of bedding follow the inclination of the surface of the hill. Between Blake Hill and Galway there is a low pebble ridge.

Between Ballyvaughan and Black Head on the opposite side of the bay, many perched blocks of limestone are to be seen. The limestone rocks by Black Head are rounded in large curves, apparently by ice, but are now through denudation breaking up; but through it all the rounded outline is plainly to be perceived. In remarkable contrast to this are some of the escarpments of limestone, so regular in bedding and jointing as to look like masonry.

In the Fermoy Valley a very instructive deposit of Drift is to be seen. The stream cuts through what appears to be the remains of a great moraine, which, excepting for the stream-gully, completely blocks up the valley mouth. The stream is at one side of the valley, and brings down fine mud like a glacier river. At one part the stream runs over a rocky cascade, showing that the surface of the rock is in part rugged below the moraine matter. At one section disclosed by the stream, I saw a limestone block embedded in the moraine, measuring 9 feet long. Following up the road, we find that the back part of the moraine slopes in the opposite direction to the valley, which then begins to widen considerably. The interior may be a rock basin filled with consolidated mud. There do not appear to be any granite blocks about; but in the road from Ballyvaughan to Corkscrew Hill there are a good many granite boulders built into the coping of the wall.

INTERPRETATION OF THE IRISH DRIFT.

It may perhaps be considered presumptuous of me to express an opinion on the classification of the Irish Drift after so short an acquaintance with it. A new

observer can however often see things that do not strike those who are familiar with the object. Besides I was on the look out for any clue that might assist me with our own Drift, which you know I have long been studying. I travelled with Professor Hull's book on the Physical Geology of Ireland in my hand.* So far as I could understand, and I hope he will correct me if I am wrong, he classifies the sort of Drift I have just described about Galway as Lower Boulder-clay. As he adopts the threefold division, first applied by him to the Lancashire Drift, I presume he considers this the equivalent of the lower part of the clay at Blackpool. This is, to say the least, misleading. What Hull calls the Lower Boulder-clay in Ireland, is a deposit of an entirely different nature to that of Lancashire, which is undoubtedly *marine*, containing rounded boulders of travelled stones as well as shell fragments. Whereas the Irish Lower Boulder-clay is distinguished by the local character of the stones it contains, the absence of shells or shell fragments, and the general appearance it bears to moraine matter. It is a pity Professor Hull, before committing himself to this classification and what it involves, did not state the grounds which led him to adopt it.

Not less unwarrantable in my view is the description of the Wexford gravels, and those discovered by the Rev. Maxwell Close at Ballyedmonduff, as "Interglacial." It is really astonishing on what slender foundations these stupendous theories are built. If what is called the Upper Boulder-clay lay upon gravels containing similar species to those of the high level gravels, and these were of a type frequenting warm seas, and the Upper Boulder-clay itself contained shells

* Unfortunately Mr. Kinahan's "Geology of Ireland" was not then published.

decidedly arctic in character, there might have been *a priori* grounds for considering these high level gravels "Interglacial." It is not pretended that any such marked distinction is found. The whole classification, to my mind, is an unscientific assumption; facts being fitted into theory, instead of theory being the explanation of facts.

Nothing does more harm to geology than these hasty generalisations.

For what they are worth I will now give you my own explanation of what I have seen; premising, however, that these views are only provisional, to be modified when a better explanation is brought forward, or further facts forthcoming.

In comparing the Irish Drift deposits with those of England, the principal difference that strikes an observer is the great extension in England of marine clays and sands, and their apparent replacement in Ireland with Boulder-clays of a subærial nature. I say apparent replacement, because a visit to the mountainous districts of England and Wales will satisfy any investigator that the same kind of Boulder-clay occurs here as in Ireland, modified by the nature of the parent rocks as in Ireland. It appears to me that the Boulder-clay of Galway Bay, Clew Bay, and similar submerged valleys in Ireland, has been directly laid down by glaciers; and, from the extremely fine nature of the clay itself, I argue that it has been deposited in water, probably when the glacier has been in a state of semi-flotation as it entered the sea; or, in some cases, perhaps where it terminated in fresh water lakes, either rock basins or moraine dammed up valleys. It is evidently not a marine deposit from drifting ice; nor could it have been formed on dry land; the extremely fine nature, combined with the great mass of

material forbids the supposition. The striations of the stones are of an indefinite character. The enormous blocks of planed and grooved stones in the Lancashire Marine Drift are in striking contrast to the local irregular and furtively scratched stones of the Irish Glacial or Lower Boulder-clay On the east coast, about Belfast Lough, the Boulder-clay is, I should say, undoubtedly marine, of the same nature as the Lancashire Low-level Boulder-clays and sands, all of which I classify together as marine.* The section of Drift at Larne I have described I look upon as all marine, modified by the detritus or submarine *talus*, due to the presence of high land close bye.

The Esker deposits I unfortunately had no opportunity of closely inspecting; but between Galway and Dublin on the great central plain they are to be distinguished from the train, and from this position I have several times looked at and thought about them. Dr. King informed me that their marine origin was not clearly established by fossil evidence, as it was doubtful if marine shells, or in fact any shells, had been authentically taken from them.

Still I think it is probable they are marine, as nothing but strong currents will satisfactorily account for them. The high level gravels I consider as synchronous with our own high level gravels of Tryfaen and Macclesfield, and I attach no weight to the slight differences of *facies* of the shell fauna, considering it may arise from local peculiarities. From physical considerations, I consider the submergence in England and Ireland during the Glacial Period was general.

* This view has since been confirmed by information received from Mr. Josh. Wright. At Woodburn Glen *Leda pernula* and *Leda minuta* occur in the clay with the valves attached; also many Foraminifera, including *Polystomella arctica*, which is found fine and in abundance.

The materials of the Esker ridges, which by a reference to the "Reports of Commissioners Appointed to Enquire into the Drainage of Irish Bogs," 1811–14, are shown generally to bound the bogs, and no doubt to a considerable extent cause them, have been derived largely from the Boulder-clays. They consist mostly of limestone pebbles, and the same gravelly formation underlies the greater area of the bogs themselves, itself frequently overlaid by a thin stratum of blue clay, from two to five feet thick. I look upon the Eskers as the last remnants of the expiring Glacial Period. I see no warrant whatever for classifying them as "Interglacial," except it be to harmonise them independently of facts with a preconceived theory.

It is now over five years since I wrote Part I. of "The Drift Beds of the North-West of England,"* and my views, so far as they are there expressed of the classification of the Glacial deposits of Lancashire and Cheshire, I have seen no reason to change, though I have been, as you are aware, engaged in investigating the deposits ever since. It appears to me that the same classification will hold equally good for the Glacial deposits of the opposite side of the Irish Sea. First we have the ice-worn surfaces of the rocks, such as those of Fairhead, corresponding to the planed and grooved surfaces found under the marine clays of Lancashire. Then the true Glacial clays of Galway and Clew Bays, synchronous with similar Boulder-clay found in most Welsh valleys. After this comes the marine Boulder-clays of Belfast and Larne, corresponding with our Low-Level Boulder-clay and sands. Of the Esker period we hardly possess a development, doubtless from the nature of the materials, as well as the contour of the country not

* Quarterly Journal of Geological Society, vol. xxx., pp. 27–37.

being favourable to the accumulation of such a deposit; but after inspecting the section of gravel drift at Leyland, described by Mr. Darbishire,* I think it not improbable that it may be of the same age as the Irish Eskers, as it is really a mound or ridge lying on the Boulder-clay.

I have pointed out that when the rock is soft in Lancashire, that in place of the marine Boulder-clay lying on planed and grooved surfaces, there is a deposit of red sand between the clay and the parent rock, due doubtless to the same cause that planed the rock. This is a subaërial Glacial deposit, and no doubt correspondent to the oldest of the Glacial clays of Ireland. At the same time it is possible these Glacial clays of Galway and Clew Bays may represent all the time from the grooving of the rocks of the Lancashire plain to the last deposit of marine Drift. But this is a question that will require further investigation; it does not affect the broad outline of the classification I adopt.

With this slight sketch of Irish scenery and Geology, I commend the further study of them in the field to other members of the Society who are in search of health, amusement, and instruction.

* Quarterly Journal of Geological Society, vol. xxx., pp. 38–40.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
S. J. MACKIE, F.G.S., F.S.A., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
EDWARD W. BINNEY, F.R.S., F.G.S., Douglas, Isle of Man.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D. Sc., Queen's College, Galway.

MEMBERS.

ABRAHAM, J., Riverham, Grassendale Park.
87, Bold Street.
ADDISON, W. H., Deaf and Dumb Institute, Oxford Street.
ARCHER, F., B.A., Boundary Cottage, Crosby.
14, Cook Street.
*BEASLEY, H., Acre-field House, Woolton.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
BRAMALL, H., 3, Balmoral Road.
BREWSTER, C., Rev., 14, Selborne Street, Prince's Road.
BROWN, C. H., Low-wood, Alexandra-road, Southport.
*BROWN, J. CAMPBELL, D. Sc., F.C.S., 27, Abercromby Square.
COOGAN, P. M., C.E., 28, Green Lawn, Rock Ferry.
COOKE, W. H., Aughton Springs, Town Green, Ormskirk.
DAVIES, C., 8, Kinglake Street, Edge Hill.

DAWBARN, W., Elmswood, Aigburth.
The Temple, Dale Street.
DODD, J., 2, Derby Terrace, Rock Ferry.
*† ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackin's Hey.
FABERT, C., 3, St. James' Walk.
FITZPATRICK, M., 62, Seel Street.
FITZPATRICK, J. J., 62, Seel Street.
FOSTER, E., 7, Newstead Road, Smithdown Lane.
FOSTER, R. M., 34, Oxford Road, Waterloo.
GREEN, A., York House, Old Chester Road, Rock Ferry.
9, Canning Place.
GRIFFITHS, J., 14, Queen Street, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B., Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W.. B. Sc., 67, White Rock Street.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport,
JEVONS, G., Jun., 5, Chapel Street.
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
KERSHAW, J., Neville Street, Southport.
LEA, T., Vale Cottage, Huyton Quarry.
LEIGH-GREGSON, S., Aigburth Road.
Slater Court, 5, Castle Street.
LEWIS, J. T., 131, Park Street.
MACKINTOSH, D., F.G.S., 32, Whitford Road, Higher Tranmere.
*McCLAY, J. L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MAYER, J., F.S.A., Pennant House, Lower Bebington.
*MOORE, T. J., C.M.Z.S,L., 44, Osborne Road, Tue Brook.
Liverpool Museum.
*MORGAN, ALFRED (Honorary Treasurer), 2, Rathbone Terrace, Wellington Road, Wavertree. Office, 126, London Road,
MORTIMER, Captain, Liverpool.
*†MORTON, G.H., F.G.S., F.R.G.S.I. (Honorary Secretary), 10, Sheil Road. 122, London Road.
†MOTT, C. G., Sunnyside, Cavendish Road, Birkenhead.
McMILLAN, A., Conway, North Wales.

PATERSON, J., Palmyra Street, Warrington.
PEARSE, W., Wellington Buildings, Chapel Walks.
Green Bank Farm, Wavertree.
*†PICTON, J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
PEARSON, J. E., Golborne Park, near Newton-le-Willows.
QUILLIAM, W. H., Fern Bank, Fairfield Crescent.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Holt Hill, Tranmere.
ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
*SEMMONS, W., 20, Canning Place.
STONE, T., Jun., Newton Park, Newton-le-Willows.
STRONGITHARM, G., 77, Whetstone Lane, Tranmere.
SPARGO, E., Bangor, North Wales.
SHERLOCK, C., 63, South John Street.
WILSON, W. H., St. Michael's Hamlet, Aigburth.
31, Wapping.
WRIGHT, B. M., F.R. Hist. Soc., 90, Great Russell Street, Bloomsbury, London.
WARD, T., Northwich, Cheshire.
WARD, J. R., 57, Garth Road, Bangor, North Wales.
WOOD, J. J., Olive Mount, Wavertree.
20, Lord Street.
YOUNG, H., 12, South Castle Street.

---

* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-FIRST.

1879-80.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

PART II.—VOL. IV.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1880.

OFFICERS, 1879-80.

President.

WILLIAM SEMMONS.

Vice-President.

J. CAMPBELL BROWN, D.Sc., F.C.S.

Ex-President.

HUGH F. HALL, F.G.S.

Honorary Treasurer.

ALFRED MORGAN.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

HENRY BEASLEY.

T. J. MOORE, C.M.Z.S.L.

T. MELLARD READE, C.E., F.G.S.

ISAAC ROBERTS, F.G.S.

CHARLES RICKETTS, M.D., F.G.S.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-FIRST.

OCTOBER 14TH, 1879.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been audited by Mr. W. SEMMONS and Mr. ISAAC ROBERTS.

The Anniversary Address was read by the President.

NOVEMBER 12th, 1879.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

PROF. JOHN W. JUDD, F.R.S., was elected an Honorary Member of the Society; and W. S. BARRETT, J. A. EDE, J. H. LIGHTBODY, S. VEEVERS, and the REV. Z. T. DOWEN, were elected Ordinary Members,

The following communications were read:—

NOTES ON FLINT IMPLEMENTS, FROM A RAISED BEACH, AT KILROOT, CO. ANTRIM.

BY FRANCIS ARCHER, B.A.

NOTES ON THE CARBONIFEROUS LIMESTONE, NEAR SKIPTON, AND NORTH DERBYSHIRE.

By Charles Ricketts, M.D., F.G.S.

DECEMBER 9th, 1879.

The President, WILLIAM SEMMONS, in the Chair.

The following communication was read:—

REMARKABLE PEBBLES IN THE BOULDER CLAY.

By Charles Ricketts, M.D., F.G.S.

JANUARY 13th, 1880.

The President, WILLIAM SEMMONS, in the Chair.

The following communication was read:—

THE GLACIAL BEDS OF THE CLYDE AND FORTH.

By T. Mellard Reade, C.E., F.G.S.

FEBRUARY 10th, 1880.

The President, WILLIAM SEMMONS, in the Chair.

Mr. G. H. Morton, F.G.S., exhibited and described his New Geological Map of Liverpool. It contained a much larger area of the Keuper formation than the maps published by the Geological Survey, and will probably appear in a new edition of the "Geology of the Country around Liverpool."

MARCH 9TH, 1880.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

The following communications were read:—

NOTES ON THE KEUPER SANDSTONE, LIVERPOOL.

By ROBERT BOSTOCK.

NOTES ON HUMAN SKELETONS AND TRACES OF HUMAN WORKMANSHIP FOUND IN A CAVE AT LLANDUDNO.

By R. A. ESKRIGGE, F.G.S.

WITH

MEMORANDUM ON THE REMAINS FOUND IN THE SAME CAVE.

By PROF. BOYD DAWKINS, F.R.S.

PRESIDENT'S ADDRESS.

By William Semmons.

In considering a subject for a Presidential Address to this Society, the difficulty of composing it arises rather from the vastness than from the restriction of range of field presented to the view. The multiplicity of subjects embraced by the term Geology enables us, without travelling out of our legitimate field, to avail ourselves equally of the latest information derived from scraping the bed of an ocean depth and that derived from scanning the surface of a distant planet. As a consequence, the ceaseless activity of various workers in the department of original research is constantly bringing fresh information before us, whilst in the more elevated region of Philosophical Geology we find the same restless spirit in the search after truth manifested in the examination, revision, and often rejection of old theoretical speculations and the substitution of new ones. These will in their turn doubtless pass through the same ordeal.

> "These little systems have their day,
> They have their day, and cease to be."

Through the labours of the deep sea dredgers of the "Challenger," "Porcupine," &c., we find that a flood of light has been thrown on the Physical Geography of our globe at a time which, geologically near, is indeed historically remote. The fabled Atalantis of the Greeks seems again to arise from the ocean depths; its mountain ranges are brought before us, and the position of its volcanoes, which cast such a lurid glare over the Miocene epoch, are even surmised at.

The labours of the investigators of the Extra terrestrial rocks are certainly now enabling us to arrive at some more rational basis for the consideration of the composition of the earth's interior. On all sides we see vast fields yet unexplored, showing us how little we yet know of the Records of the Rocks, and how many Medals of Creation lie waiting for our gathering. Take, for example, the work of Haydyn, King, and others of our American brethren, in their examination of Colorado, &c. We seem, when reading their descriptions of wondrous canŏns, &c., to be away from this prosaic planet and to be placed in a fairy-land of Titanic grandeur and picturesqueness.

Since Geology may fairly be called a world-wide science, it is with interest and pleasure we notice the International Geological Congress, which held its first meeting at Paris last year. Though exception may possibly be taken to some of the representatives of the various kingdoms, the meeting of eminent Geologists from America, Australia, Belgium, Italy, Spain, Russia, &c., cannot fail to advance the knowledge of our science, and I look forward with confidence to a more complete restoration of the stone book of Nature when we find workers from such widely separated districts conferring together. We shall all welcome the report of the Committee deputed by the Congress to consider the questions of the unification of Geological signs, the limits and characters of certain formations, and the respective values of the Fauna and Flora in defining beds.

The decision of the Liverpool Town Council to discontinue the boring at Bootle, when a depth of 1,300 feet had been reached, has been viewed with regret by Geologists. It would have been interesting to have known to what depth the Triassic rocks extended, and if

the universal opinion of Geologists were confirmed, that Coal could be worked under this town at a moderate depth. While on the subject of borings we cannot but notice those at Turnford and at Ware, in the latter of which beds of Wenlock Shale are found immediately beneath the Gault. The results of the various borings have now shown conclusively that the grand generalization of Mr. Godwin Austen in his paper "On the possible extension of the Coal Measures under South Eastern Counties of England," read in 1855, are in the main correct. We must all hope that this eminent Geologist may yet complete a palæographical atlas, in providing the materials for which he has already done so much. The "Palæozoic ridge" may now be considered as having fully established itself. Ought we not now to call it the Godwin Austen ridge?

The Bank of Geological time which was considered at the date of the appearance of the first edition of the "Origin of Species" to have unlimited capital, seemed to have it vastly reduced by the efforts of Sir W. Thomson. On physical and mathematical grounds (all of which are, however, disputed by others almost equally competent) this eminent mathematician placed a restriction on the time in which all our known Geological operations must have been performed. This tendency to restrict Geological time, the effect of which could be plainly seen in Prof. Huxley's address to the Geological Society in 1859, seems to have reached its full development at the time of the meeting of the British Association at Glasgow, where Prof. Young conceded that the fifteen million years which Prof. Guthrie Tait—less liberal than Sir W. Thomson—allowed as the measure of time, was sufficient for the working out of the Geological problem. The tide of thought has

since then set in in a contrary direction, and Physical Geologists, pointing with confidence to their unconformities and other proofs, demand a practically unlimited period. As Prestwich long ago remarked, the fundamental truths of Geology are as well established as those of Astronomy or Mathematics, and it is for Physicists to consider whether the premises on which their conclusions are based are absolutely and incontrovertibly true. Our member, Mr. T. Mellard Reade, C.E., F.G.S., has attacked this question from another point of view, which Prof. Ramsay gracefully calls "a new one to me." Proceeding on the basis of the gradual progress or evolution of time, as the present is approached, he arrives at the conclusion that the elimination of the calcareous matter contained in the sedimentary crust of the earth must have occupied at least 600 millions of years. Mr. Reade gives from the Laurentian to Silurian, from Old Red to New Red Sandstone, and Jurassic to Post-pliocene inclusive, a period of 200 millions of years each.

The abhorrence of Nature to artificial classifications may be seen in Geology, as in other branches of science. How many attempts have been made to classify the crystalline rocks? In the past year this difficult task has been undertaken by that most eminent mineralogist, Prof. Dana. As might have been anticipated, the chemical relations of the rocks form the basis of this elaborate analysis, and we are to deal in future with the Mica and Potash Felspar series, the Hornblende and Potash Felspar series, the Hornblende and Soda-Lime Felspar series, the Pyroxene Garnet Epidote and Chrysotile rocks, containing little or no Felspar, and the hydrated magnesian and aluminous rocks, containing little or no Felspar. Some of the difficulties inseparable from this

method of classification have been clearly pointed out by Prof. Bonney. I would only here suggest that the origin of a rock has claims to consideration as well as its mineralogical composition. It seems a very arbitrary law to separate Mica from Talcose and Chloritic Schists, and place the former with Granites, and the two latter with Serpentine.

Whilst on the subject of classification, it is fitting to pay a tribute of respect to one, so lately removed from us, whose clear and lucid intellect exercised so great an influence in directing the minds of Geologists to the necessity of "arriving at a common ground for all nations in respect to the important matter of rock nomenclature." I allude to B. Von Cotta, of Freiberg. Yet even his latest edition of "Rocks classified and described," though of the highest value, is necessarilly imperfect, for as the gifted author remarks, "Science marches with uninterrupted steps towards new fields of discovery, and every year alters its aspect."

It is not within the purpose of the present address to notice the additions to our Palæontological knowledge in the past year, but it seems almost necessary to call attention to the discovery in the Jurassic formation of the Rocky Mountains, by Prof. O. C. Marsh, of the remarkable reptile which he has called the "Sauranodon," and on which he has founded a new order, "Sauranodonta." This animal is so closely allied to the Ichthyosauri, that their respective vertebræ ribs and other portions of the skeleton cannot be distinguished from each other. The jaws, however, appear entirely edentulous and destitute of even a dentary groove. It is an interesting fact to find that this reptile, which bears the same relation to the Ichthyosauri as the Pteranodonta do to the Pterodactyls, should be found in the same region.

Monstrum horrendum informe ingens cui dens ademptus.

Nor ought we to fail to notice here the researches of Prof. Seeley on the development of the Ichthyosauri, which seem to show that these immense reptiles were viviparous.

Those Geologists who have had the privilege of examining the splendid collection of chalk fossils in the possession of our member, Mr. Chas. Potter, will not be surprised to find that his magnificent specimen of Edaphodon Sedgwicki has "the place of honour" in the monograph, by the Assistant-naturalist of the Geological Survey, on "The Chimeroid fishes of the British Cretaceous rocks," and to find it there described as the most complete Chimeroid at present known. It is only necessary to glance over the memoir to see the light thrown on the genus by this single specimen, and we must all congratulate Mr. Potter on so public an acknowledgement of his good fortune and perseverance.

The application of the microscope to Geological research has of late been vastly extended. Mr. Sorby (the present President of the Geological Society of London), in his classic paper read before that Society in 1858, "On the Microscopic Structure of Crystals," and in other papers of a similar character, pointed out the high importance of this instrument to the working Geologist. Prof. Maskelyne, too, in 1861, by the use of Polarised light, was enabled to point out some interesting facts as to the mineralogical composition of Meteorites. But by the labours of Zirkel, Rosenbusch, Allport, Bonney, Judd, and others, the most remarkable insight has been gained of the structure and composition of Igneous and Metamorphic rocks. The late David Forbes, who in the course of his extensive travels was perhaps the first English Geologist to become acquainted with

the remarkable development of Micro-Petrography in Germany, well remarked, in 1865:—"A microscopic examination of the close-grained and more compact varieties effects completely that which the naked eye can do in the case of the more crystalline and coarser grained rocks." (B. Assn. Report, 1865.)

One has only to turn over the pages of the Journal of the Geological Society of London for the past four or five years to compare the descriptions of rocks with those given 20 years since, to realise the fact that a new science has grown up in our midst. The valuable chemical analyses of any particular rock under discussion are not omitted, but we now have in addition full macroscopic and especially microscopic examinations. It would be quite impossible to bring before your notice the vast additions to our knowledge of even the Igneous group of rocks in the time at our disposal this evening; and I therefore purpose to direct attention for a few moments to that great and most important class of rock which are known as the Granites. I have chosen these rocks as the principal subject of my address, as I thought the consideration of the researches of late observers and the deductions made therefrom would, perhaps, be of greater interest and value than if we took a wider field.

Granite is, as its name implies (derived from *granum*, a grain), a rock of granular crystalline composition and aspect. The grains may be of small size or large, like those described by Th. Scheerer ("Pogg. Annual," lvi, p. 489) in Norway, where the three typical minerals composing it are in large crystals, the Orthoclase being one cubic foot, Mica one square foot in dimensions, and the Quartz in still more considerable masses extending between them.

A few years since the minerals Quartz, Mica, and Felspar would be named as those composing Granite. Now we have to consider which variety of Felspar is meant, and which of the great group known as Mica. The Felspars of Scotland have been subjected to a close examination by Prof. Heddle, and seven distinct varieties, ranging in per centage of Silica from 69 per cent. in Albite to 45 per cent. in Anorthite, are declared to exist in the Scottish rocks. The seven are Orthoclase, Albite, Oligoclase, Andesine, Anorthite, Labradorite, Latrobite. The per centage of Silica in the Micas may be considered as being about the same in all. It will thus be seen we may have Granites in which, while the proportion of Quartz and Felspar remain the same, the quantity of Silica in the whole may vary considerably, and may, in fact, be so little as to throw the rock into what is known as the intermediate class.

David Forbes (Quarterly Journal Geo. Soc., 1872, p. 43) says: The Granites which are stanniferous in Cornwall, Spain, Peru, Bolivia, Portugal, Malacca and Australia, are all *identical* in composition. They are all composed of Orthoclase Felspar; Black or colourless Muscovite, Mica, Quartz, and more or less native Gold.

In my paper, on the mineralogical structure of some Cornish Granites (Proc. L'pool Geo. Soc., 1877-79), I gave the results of careful examination of eight varieties. These Granites have also been closely examined by J. A. Phillips, F.G.S., and S. Allport, F.G.S. The remarks of these writers on the microscopic cavities, found in the Cornish Granites, will appear in the sequel, but their remarks as to the minerals may be summarized, that in addition to Quartz, Felspar and Mica, Schorl is almost always met with, and sometimes as accessories Chlorite, Apatite, Cassitterite, Fluor Spar, Beryl, Garnet and Pinite.

The Granite of the Ross of Mull is by Prof. Haughton, described as composed of Quartz (abundant), one Felspar (a pink Orthoclase), with a little black Mica.

A Granite, from New Brunswick, shown by me to this Society last year, almost exactly resembles that of Mull.

The Granites of the Mourne Mountains, remarkable for the crystals of accessory minerals which they contain, have Albite in large quantities as their Felspar. I had often noticed that those Granites which have Albite as one of their Felspars frequently contain a large number of accessory minerals, and on inquiry I found from my friend Mr. Thos. Davies, F.G.S., of the British Museum (one of our best authorities), that in his much wider experience he had already noticed this interesting fact.

It has often been surmised by those Geologists who hold the Igneous theory as to the formation of Granite that many of the rarer elements would be found in this group of rocks on their being examined by the spectrum analysis. The researches of M. Dieulafait, lately made known, prove that out of 139 specimens of Granite, Syenite, and Gneiss, examined by this means, every one of them contained that comparatively rare element Lithium. I may here state that the mineral spring containing by far the largest proportion of that element occurs just out of the margin of one of the Granite masses of Cornwall. Again, in confirmation of these views, we notice that remarkable block or Granite described by Prof. Heddle, found near the village of Tongue, where the crystals of Amazon measuring 15″ by 10″ by 8″, contained among other minerals, Thorite and Orangite, two of the rarest to be met on the earth.

Turning for a moment to that great belt of Granitic rocks in the United States of America, which has been

worked in the field by Clarence King and in the laboratory by Zirkel, we find those of the 40th parallel divided into two groups, the one Ante and the other Post-Jurassic, and both are composed of Felspar, Quartz, and Mica. The older is characterised by the predominating Felspar being Orthoclase and by their containing no Titanite and no primary specular Iron, while the newer contain proportionately a great deal of Plagioclase, also Titanite, plates of specular Iron, are generally rich in Apatite, and the Quartzes are more often relatively rich than relatively poor in fluid inclusions. The presence or absence of Titanite had previously been clearly pointed out by Clarence King, and used in this district as a marked distinction of age.

The Tourmaline Granite of Monzoni is a well-marked Granite of a red colour, made up of Orthoclase of a more or less deep pink tint, white or greenish Plagioclase, Grey Quartz, and Biotite.

The remarkable rock of the Ponza Islands, from which such important deductions have been drawn, has an ultimate chemical composition identical with that of many Granites, its minerals Orthoclase, Oligoclase, or Albite, Quartz, Mica, or Hornblende are precisely those of ordinary Granites.

The lavas of the central volcano of the Lipari Islands are composed of one or more species of Felspar, Hornblende, or Mica, and some fine Quartz. They are by many writers termed Granites.

The well-known "Quartz Porphyry" of Botzen, which was by earlier Geologists regarded as a Granite, is composed of Orthoclase with Quartz, while associated with it is found a rock (Tschermak's) Quartz Porphyrite, in which numerous large grains of Quartz, with smaller crystals of Plagioclase, Felspar, and Biotite are embedded

in a compact dark-coloured base. It is an exact representative among the older rocks—being of Permian age—with those remarkable Quartz Andesites or Dacites, which we will now briefly describe.

In the interesting volcanic district of Schemnitz, Hungary, is found a series of Granitic rocks, containing Quartz, Mica, or Hornblende and Felspar. The quantity of Quartz is variable, being sometimes a large proportion, and the predominating Felspar is of the "*Basic*" type—either Labradorite or some variety intermediate between it and Andesine. These Dacites, so called from their being found in the ancient Dacia, are of the highest interest, from the fact of their containing free Quartz with Basic Felspars, and thus demonstrating the fallacy of the idea that the Felspar in a rock containing free Quartz must necessarily be Orthoclase. I need only refer to that most valuable paper of Prof. Haughton's, where on this assumption he proceeds, by "a masterly method of mathematical analysis," to calculate the proportions of each of the minerals composing the Leinster Granite, in proof of the predominance of this idea in the minds of our old masters in Petrology. Thrice to slay the slain, we may notice that the Dacites from the Bihar and Rodnær ranges in Transylvania, described by Dr. Dölter, Banatite from Banat, described by Cotta, Tonalite from the Granite mass of Adamello, and a rock from the Euganean hills (both of the latter being described by Vom Rath) are examples testifying to the same fact. The whole of these rocks contain from 66 to 68 per cent. of Silica. In the words of Professor Judd, we may say that every attempt to give Granite a purely mineralogical definition has failed, in consequence of the variation even in parts of the same mass in its constituent minerals. The texture of the rock, however,

appears to afford surer ground on which we may base a definition.

Before leaving the question of the minerals composing Granites, we will for a moment glance at those fluid inclusions found in them, and on which so much light has been gained in the past few years. I well remember the first time I looked at a piece of Granite, from Shap, which had been placed under a high power. The cavities in the Quartz crystals, partially filled with liquid, had in them a small bubble, which seemed to be constantly in motion. As described by Zirkel, it seemed a thing of life. These cavities in Quartz crystals vary from extreme microscopic minuteness to that seen in the large Quartz crystal in the British Museum, 1½-inch long, which contains several crystals of Iron Pyrites.

The Rev. J. Clifton Ward, F.G.S., in his most valuable series of papers on the "Granitic, Granitoid, and Associated Rocks of the Lake District," shews that the Quartz crystals of the Granites found in that locality have an almost infinite number of cavities in them, which are partially filled with liquid, the proportion of the empty space in the cavity to its whole varying from $\frac{1}{8}$ in the Eskdale Granite to $\frac{3}{100}$ in that from Skiddaw. J. A. Phillips, F.G.S., in his paper on the "Rocks of the Mining Districts of Cornwall," says "numerous microscopical cavities, partially filled with liquid, are observable in the Quartz of all the Cornish Granites; some, on the other hand, are apparently full, while others are entirely empty."

S. Allport, F.G.S., a most careful observer, says (on the metamorphic rocks surrounding the Land's End mass of Granite), "Fluid cavities are abundant in the large masses of Granite, &c." A remarkable example occurs in the Granite in contact with the Slate at Mouse-

hole; in a single grain of Quartz there are several fluid cavities containing active bubbles, three of which exhibit widely different proportions to the size of the cavities. There are also not a few cavities which appear to be quite filled with a fluid of similar refractive power to that containing bubbles. There are also many cavities containing cubic crystals in addition to liquid and vacuity; these are shown by Mr. Sorby to be either sodic or potassic Chloride, and are, no doubt, preserved in a saturated solution; the fluid is, therefore, probably of a different density from that which there are no such crystals. This is also proved by moving the stage of the microscope in order to cause the bubble to move from one end of a cavity to another, as the motion is comparatively rapid in some, while it is so sluggish in others as to be more like the rise of a bubble in oil than in water.

In his remarkable work on "Microscopical Petrography," issued by the United States Government as one of the series on the Geological Exploration of the 40th Parallel, Prof. Zirkel, of Leipsic deals with these inclusions in a very exhaustive manner. The completeness of the examinations may be inferred from the fact that more than 2,500 thin sections were studied under the microscope.

I will proceed with a brief description of what seems to me to be some of the most interesting of them.

In the Quartz of a Granite from Clark's Peak is found the largest number of fluid inclusions that any rock constituent has ever been seen to hold. They consist of water. The bubbles in the simple inclusions here are of unusual mobility and restlessness. This Granite also contains a mineral supposed to be Zircon, pierced by Apatite prisms.

In a coarse-grained Granite from Havallah range the Quartz grains have liquid inclusions containing most beautiful crystals of salt, and sometimes black minute microlites. These are so very minute that one cubic millimetre of Quartz contains 10,000 of them. They cross each other confusedly, often forming a web, or diverging from one point in all directions like roots from a stump. These are Muscovite. Another Granite from same locality contains Quartzes in which every fluid inclusion bears a salt cube, many of them even having two of these little crystals.

In a rock from Rawling's Peak, Wyoming, which Zirkel calls between a Granite and a Gneiss, the Quartz is rich in fluid inclusions, which contain with unusual constancy little cubes of Chloride of Sodium, the solution being saturated with Chloride of Sodium—in addition to the bubble. The spontaneous motion of the bubbles here visible prevents any doubt of the liquid nature of the surrounding medium. The small cubical crystals in the liquid look as if made from glass. Sometimes they are rounded off at the corners, and a very fine striation occurs here and there on the quadratic forces like on cubes of kitchen salt. Zirkel says such inclusions of dissolved Chloride of Sodium with included salt cubes have been found thus far in the Quartzes of the Zircon Syenite from Laurig, Norway; the Diorite from Quenaast, Belgium; the Granites of Johann Georgenstadt, Saxony; Ding Dong Mine, near Penzance; Trevelyan, near St. Ives; the Goatfell, Isle of Arran; the Felsitic porphyry (Elvan) from Withiel, Cornwall, and from the western coast of Arran; the Post-Liassic Serpentine porphyry, Skye; the Propylitic rock from Bonsa Banya, Transylvania; and in the Gneissic crystalline slates of the Trossachs, also in the Nepheline and Calc spar of blocks ejected

from Vesuvius. In the Granite from Granite Peak the Quartzes contain double inclosures of an unusually large size. The innermost fluid is liquid carbonic acid, the bubble reappearing by a diminution of the raised temperature in all neighbouring inclusions of this kind at 31° cent. It seems probable that the outer boundary of this liquid carbonic acid is not a liquid but a solid mass. In addition to these double inclusions the Quartzes of this Granite envelope also the more common single inclusions of liquid carbonic acid, and along with these are other cavities filled with a fluid whose bubble does not disappear even at the high temperature of 100° cent. Without doubt the latter is chiefly water, with, perhaps, a small amount of dissolved carbonic acid.

Liquid inclusions of carbonic acid are at present also known in the Quartzes of the Granitic Gneiss of the St. Gothard, in the Quartzes of the gray Gneiss from Frieberg, Saxony, and of the Granite from Augrushmore, Ireland; in the Topazes of Rio Bolivante, Brazil; in some sapphires; in Augites, Olivines, and felspars of Basalts from Rhenish Prussia, Wurtemburg, Hesse, and in the greenish Apatite from Pfitsch Valley in the Tyrol.

The paper by H. C. Sorby, F.R.S., "On the Microscopical Structure of Crystals indicating the Origin of Rocks and Minerals," (see Quarterly Journal Geo. Soc., 1858, pp. 453–500) cannot be passed over without notice, as it has formed the starting point of so many later investigations. Mr. S. remarks: "Besides fluid and stone cavities, the Quartzes of Granite contain vapour cavities like those in minerals from modern volcanoes. On the whole, then, the microscopic structure of the minerals in Granite is in every respect analagous to that of those formed at great depths and ejected from modern volcanoes or that of the Quartz of the

Trachyte of Ponza, as though Granite had been formed under similar physical conditions, combining at once Igneous fusion, Aqueous solution, and Gaseous sublination."

A consideration of the composition of these fluid inclusions appears to lead to the conclusion that there is the closest possible relation between Granite and purely Igneous rocks; liquid inclusions of carbonic acid being found in Basalts and Granites, and of solutions of chloride of sodium in Diorites, Felsites, and Granites. The presence of water has been thought to militate against the idea of the former molten condition of a rock, but the remarkable discovery by Zirkel in a Rhyolitic breccia from Mullen's gap of "the most perfect fluid inclusions with a moveable bubble in each in a glassy base" proves that this is not necessarily the case; so that, as Zirkel adds, "the fact that fluid inclusions occur in the Quartzes of Granite cannot by any means be used as an argument against the igneous origin of this rock." The leucites of the lavas from the Capodi Bove, the Soltafara, &c., also have glass inclusions, which bear, instead of the usual interior empty cavity, a liquid in which there is a moving bubble. When we look at this minute microscopic object found in an obscure rock of the great American continent, and when we reflect on the light it has thrown on Rock formation, we may well say with Sorby, "there is no necessary connection between the size of an object and the value of a fact; though the objects described are minute, the conclusions to be derived from the facts are great."

We will now consider the speculations which from the examinations of these cavities have been advanced as to the probable depth at which Granites have been found. Sorby, as you well know, reasoning on the

premises (1st), that the cavities were exactly filled with fluid at the time the crystals were formed; (2nd), that the vacuity was produced by cooling; (3rd), that the quartz of the various igneous rocks crystalised at about 360° c., concludes that the following represent the depths at which several Granites and Elvans have been formed:—

Elvans at Gwennap	18,100 ft.
Do. at Swanpool	53,900 ,,
Granite at St. Austell	32,400 ,,
Do. at Ding Dong	63,600 ,,
Recent Veins of Aberdeen Granite	42,000 ,,
Centre of main mass of Aberdeen do.	78,000 ,,

The mean depths of consolidation he estimates to be 50,000 ft. for the Granites of Cornwall, and 76,000 feet for those of the Scottish Highlands.

The Rev. J. Clifton Ward, proceeding on the same assumptions and using R. W. Fox's estimate of increase of heat towards the earth's interior (1° F. for 49 ft.), and taking also into consideration the connection of the Granite with the surrounding masses of sedimentary or volcanic rocks, arrives at some most interesting results. He calculated, from an examination in the field, that the Skiddaw Granite was formed at a maximum depth of 30,000 feet, while the pressure indicated by the bubble in the fluid cavity is 52,000 ft. The Eskdale Granite he estimates from field examination formed under a pressure of 22,000 ft., the cavity indicating 42,000 ft. while that of Shap he gives at 14,000 ft. and 46,000 ft. respectively. The surplus pressure of about 20,000 ft. in the Skiddaw and Eskdale Granites and 32,000 ft. in that of Shap probably acted outwards, and effected elevation, contortion, and metamorphism. In the case of the Sha Granite, from the very large surplus of

pressure and the nearness to the surface at which it consolidated, he thinks it may be taken to represent an immature volcanic vent.

Such are some of the interesting conclusions which have been deduced from these remarkable cavities. I will now briefly proceed to describe some of the difficulties which prevent our entire acceptance of the conclusions. In the first place, when we look at the depths at which the Elvans at Swanpool and Gwennap are respectively formed, or even the Granites at St. Austell and Ding Dong, we cannot fail to notice their extreme diversity. In the case of the Aberdeen Granites the conclusions drawn from the examinations of the bubbles confirm those drawn by the field Geologist that the centre portion of the mass was probably consolidated under the greatest amount of pressure. But in the case of the Elvans we find that at Swanpool, which is found in the clay state to the south of the Granite mass of the Penrhyn district, is said to have been consolidated under a greater depth by about thrice that of the Gwennap Elvan, which is found in the immediate proximity of the Granite, where so many productive mines have been met with. These conclusions seemed so inconsistent with one another that I could not but consider the evidence was somewhere at fault, and an examination of the writings of other authorities have compelled me to question altogether the reliability of any deductions which have been drawn from examinations of these fluid cavities as to the depth Granites or Elvans have been formed. J. A. Phillips says, reasoning from the data on the occurrence of full, partially full, and empty cavities: "After a series of experiments on this subject, I have arrived at the conclusion that any method of determining the relation between the cavity and bubbles by measurement must

necessarily be beset with grave difficulties, and that the disappearance of the latter on the application of heat must take place at very varying temperatures. Such being the case, any calculation based thereon can be reliable only within certain limits, and if the presence of full fluid cavites be admitted, for which there is the same evidence as for the occurrence of vapour and gas cavities, all such calculations must be necessarily fallacious." Zirkel says that "the calculation by which the temperature at which a rock was formed is deduced from the proportion of the bubble to the liquid is so very doubtful as to afford no certain data, although it would be otherwise of great value to Geologists. Fluid cavities are *constantly* met with in the *same* crystals in which bubbles vary greatly in relative size; large cavities occur containing small bubbles by the side of small cavities with large ones. (" Mikroskopische Beschaffenneit der Mineralien und Gestein," pp. 45, 46.)

S. Allport, F.G.S., writing to the same effect as to the varying proportion of the bubbles and cavities, and also on the impossibility of obtaining accurate measurements, says he is compelled to differ from Mr. Sorby's conclusions, and further adds: "No theory can be obviously of any value as to the origin of these cavities unless it includes all the facts observed." ("On the Metamorphic Rocks surrounding the Land's End Mass of Granite."—Quarterly Journal of the Geological Society, 1876.)

Mr. Sorby, in a later paper "On the Consolidation of Granite Rocks" (Min. Mag., Nov., 1876), does not seem to mention the matter of depth of consolidation, but remarks that the very great variation in the relative amount of water and liquid carbonic acid in the cavities clearly proves that very great changes in the surrounding

circumstances took place sometimes even during the growth of one single crystal, and there is good reason to suspect that there may often have been considerable variations in temperature and pressure as well as in the relative amount of water and gas.

It would, perhaps, here be well to notice that there are rocks of Granitic structure found, the consolidation or formation of which probably took place comparatively near the Earth's surface. For my own part, I see no reason why a Granitic rock should not be formed there. The Tourmaline Granite of Monzoni, which I had the opportunity of inspecting at the British Museum this summer, through the kindness of Mr. Davies, is a well-marked typical Granite, as before described. It very much resembles some that are found in Cornwall. From examination in the field this rock is now universally regarded as of volcanic origin. Judd, in describing this district, says: "Although it cannot be proved that the Monzonite rock and Tourmaline Granite actually reached the surface, yet it is in the highest degree probable that they did so. Probably after the manner of many lavas (such as the Domites of the Auvergne) they consituted very imperfectly liquid masses, which quietly welled forth, forming dome-shaped hills, the extension of which was accompanied by but little explosive action. They certainly could not have formed extensive lava streams, nor given rise to any great quantities of Tuffs by explosive action. Scrope also, in "The Geology and Extinct Volcanoes of Central France," speaks of a Granite which was not of deep-seated origin.

We are therefore almost compelled to accept the conclusion that while by far the largest proportion of our Granites have been formed at great depths and under great pressure, there are some, perhaps many, that have

been formed at a moderate depth, and perhaps even reached the surface. The idea that all Granites have been formed under 20,000 to 50,000 feet of rock must certainly be abandoned. It seems quite possible that when the field Geologist feels himself freed from the necessity of providing for these pressures, he may have some revelations to give us of the relation of some old volcanic centres in other districts, like those given by Prof. Judd of the old line of volcanoes which once existed parallel to the range of the present Grampian Hills.

If we now consider the relations of deep-seated Granites to the volcanic rocks that have been poured out as lava, we shall often be able to trace every gradation from the rock which is perfectly crystalline, through rocks which have crystals scattered throughout a stony or sometimes even glassy base, to one that is throughout either slaggy or scoriaceous; and we further find that these characters are largely dependent on the depth at which the rock has consolidated. It will here be well to study some of these relations, and we will in the first place take some of those magnificent natural sections which are to be met with on the western side of Scotland, and which are so graphically described by Judd.

"Fortunately in some of the mountains of the Island of Mull we can trace some very remarkable series of such changes of structure, the ultimate composition of the rocks being the same. At Beinn Greig, a mountain which rises near the western end of Loch Bah to the length of 1941 feet, in the deep ravines which divide it from Beinn-y-chat and Beinn-a-Gobbhar, is found a typical Granite of the hornblendic kind. As we ascend the mountain, this Granite is found to pass by insensible gradations into a quartziferous Felsite. Still higher the

rock becomes finely crystalline or granular, the magnesian and ferruginous materials being apparently no longer separately crystallised, but diffused through the mass as colouring matters. The porphyritic structure is locally displayed by all portions of the mass alike, from the coarsest Granite to the finest-grained Felsite."

The Granite and Felsite of Beinn Greig are traversed by innumerable veins. These all appear to be of the "contemporaneous" class, and to be composed of similar materials to those of the mass itself, differing for the most part only in the degree of the fineness of grain, colour, &c. Usually the rock of the veins is of much finer grain, colour, &c.; and in some analogous cases the acid rock passes into the glassy condition, and exists as pitchstone veins traversing Granite.

Lying upon the summit and flanks of the eruptive rocks just described are sheets of lava of the highly acid variety (Felstones) often highly vesicular, and amygdaloidal in structure, which alternate with great masses of Ash, Lapillæ, and scoriaceous fragments.

At Beinn Uaig the Granite and Felsite are seen to give off great veins, which traverse the masses of felstone lava and volcanic agglomerate, producing a very sensible degree of alteration in them along the surfaces of contact; and further these veins are *seen to include masses of the traversed rock which have been caught up in them.*

At Craig Craggen we find the Granites and Felsites presenting the same relation to the overlying felstone lavas as in the two previous examples. As we trace the lavas up the slope of the mountain, the intercalated masses of agglomerate are found to become gradually thicker until they constitute the larger portion of the mass, though still traversed throughout by lava sheets and intersected by innumerable dykes. Associated with

the agglomerates are numerous ejected blocks. At its northern end the whole of the highly Siliceous rocks which compose the mass of the mountain, Granite, Felsite, Felstone lavas, and Felspathic agglomerates are seen to be penetrated indiscriminately by numerous intrusive sheets or dykes on the grandest scale, composed of various forms of Gabbro passing into dolerite and Basalt.

At Beinn More the same relations of the Granites, Felsites, Felstone lavas, Felspathic agglomerates, with the intersecting dykes of Basalt, &c., can be observed.

"In fact, by the study of the rocks of Mull," says Prof. Judd, "the Geologist is able to verify and illustrate every stage of the transformation from scoriæ to Granite."

Passing for a moment to the Grampians, we find at Beinn Nevis, on its outskirts, Gneiss, Schist, quartzite and limestone, and then a great mass of intrusive Granite. This central mass is composed of Hornblendic Granite, passing by insensible gradations into ordinary Granite on the one hand, and into Syenite Granite on the other. Ascending the central peak, we find the Granite becomes fine-grained, and as we still ascend we find the Hornblende and Mica gradually disappearing, till in the end the rock becomes a granular felsite of a pale red colour, and often more or less porphyritic in structure. At the highest portion of the mountain we find dark blue, grey, greenish and purplish felstones; and associated with these are enormous masses of volcanic agglomerates, composed for the most part of angular fragments of all sizes of felspathic materials, heaped together in the wildest confusion. A large piece of the agglomerate can be seen at South Kensington. The Felstones form great sheets, sometimes exhibiting a

rudely columnar structure, and between them lie enormous masses of volcanic agglomerate, the whole being traversed by innumerable felstone dykes. Careful study shows that the underlying Felsites and Granites send off veins into the Felstones and agglomerates.

In the famous Pass of Glencoe we find at its northern end the Silurian rocks highly metamorphosed and traversed by masses of sometimes Hornblendic Granite, but more usually of numerous varieties of red Felsite. The stratified rocks are overlain by great masses of Felstone; and these Felstones are traversed, like the stratified rocks on which they rest, by an almost infinite number of veins and dykes, composed usually of Felsite. At the southern end of the Pass there appear from underneath these altered felstones the felsites passing into Granites and enclosing masses of often highly altered Lower Silurian strata.

Judd remarks that both at Beinn Nevis and Beinn Uaig, we see the evidence that while felspathic lava streams and scoriæ were being emptied at the surface, masses of molten materials of the same composition were intruded below them, and by slow consolidature forming those bosses of felsite which pass by insensible gradations in their lower and deeper parts into hornblendic and ordinary Granite.

In the Schemnitz district the Greenstone Trachytes pass insensibly into Dacites on the one hand, and into the Andesites of the volcanic girdle on the other. The same insensible gradations in structure, from one that is either scoriaceous or slaggy to that which is purely Granitic, can be traced. Hence the Austrian Geologists have been led to the conclusion that the Granites and Syenites, the Greenstone Trachytes, and the Andesitic lavas and tuffs of this remarkable district—the value of

which in the solution of this Geological problem had been surmised with rare prescience by Sir Charles Lyell —are all part of the same great eruptive masses, and are of contemporaneous date.

In the volcanic rocks of the Lipari Islands we find the most perfect glass, passing by insensible gradations into rocks of less strikingly resinous lustre—pitchstone or Retinite—and these, through materials of pearly or porcellaneous appearance, into the most perfect stoney and crystalline (indeed, almost Granitic) masses. The remarkable rock of the Ponza Islands, of the same ultimate composition as Granite, which seems to belong to the same group as the "Nevadite" of Richtofen, is a passage rock from Granite to a true lava of almost glassy structure, "Liparite." The basis of the rock has a tendency to assume a vitreous condition, notwithstanding the occurrence in it of distinct crystals of Felspar, Quartz, Mica, and Hornblende (Judd). It is interesting to notice here that the Felspar crystals abound with cavities filled with stoney matter, while the Quartz crystals contain "fluid" cavities with air bubbles.

These examples—and I might also give many from my own observations, did time permit—seem to show that the relations between Granites and Volcanic rocks, as far as structure and chemical composition are concerned, are of the most intimate character; that, in fact, where we meet with a lava of the Acidic variety at the surface, we should, on descending into the Earth's interior, and following the rock downwards, meet with a Granite.

Is the converse proposition true? Are we to assume that near where we meet with masses of Granite the volcano at one time belched forth its flames and smoke; that fiery lava streams flowed down the sides of mountains now no more? . . . .

What vistas does not this idea bring to our imagination, when we look back on the "Gulf of Time"! Where are the old volcanoes of Leinster and of Cornwall? Have they not left a wrack behind?

When we consider the relations of Granitic masses to the sedimentary rocks surrounding, we find them in two very different characters. Hence the terms Intrusive and Metamorphic Granites have of late got into use.

The Granites of Cornwall are sharply defined where junctions of them with the Clay slates are found. At Mousehole, Cape Cornwall, and St. Michael's Mount (says S. Allport), where good sections are exposed on the shore, there is not the slightest indication of a gradation from one to the other; the mass of Granite cuts sharply through the slates, and has thrown out numerous veins, both large and small, which have penetrated them in various directions. In all such cases the slates have evidently been greatly altered along the line of junction, and fragments of them have not unfrequently been torn off, and are now enclosed in the Granite. In Cornwall, neither examination in the field nor a microscopical study of the rocks lends the slightest support to the notion that Granite is a metamorphic rock, in any proper sense of the term.

The description already given of the position of the Granitic and sedimentary rocks of Western Scotland shows that here, too, no gradation can be traced from one to the other.

In the Lake district the Rev. J. C. Ward shows that the Skiddaw Granite is also intrusive. Although Mr. Ward seems to think Granite may be considered a metamorphic rock, I am inclined to think that the views of those Geologists who contend for its purely Igneous character, are quite borne out in the case of the Skiddaw

mass. Commencing from the outside, we first meet, says Mr. Ward, with the Skiddaw Slate. "There is a complete passage from the unaltered Clay slate, through Chiastolite Slate and Spotted Schist, to Mica Schist. The junction between the Mica Schist and Granite is well defined, and there is no general transition from Mica Schist into Gneiss proper, and from Gneiss into Granite. On the whole, the evidence seems to be against regarding the Granite now exposed as the result of the extreme metamorphism of the Skiddaw Slates immediately surrounding it; but whether it may not have resulted from the metamorphism of underlying portions of the same mass, is an open question. The great contortion of the Mica Schist may be in part due to the at any rate partially intrusive character of the Granite." It is well here to notice that the percentages of Silica in the rocks named are—

Chiastolite Slate	65·725
Spotted Schist	54·448
Mica Schist	53·174
Granite	75·223

The Clay slate is of variable composition. With regard to the Quartz felsite of St. John's Vale, and the Syenitic Granite of Buttermere, which lie at the junction of the Volcanic and Skiddaw slate series, Mr. W. thinks, from their line of strike and by the occurrence enclosed in them of bands of slate or volcanic rock, that they represent the transition beds between the two series metamorphosed *in situ*. The Eskdale Granite he believes to have no direct connection with the volcanic rocks surrounding it; and the same views are held with regard to the relations of the volcanic rocks associated with the Shap Granite.

It is, however, in Ireland, where the views of General

Portlock and Sir R. Griffith on the metamorphic origin of Granite exerted such influence on subsequent observers, that we have the best instances of what may be called Metamorphic Granite brought before us. Joseph Nolan, in "the Ancient Volcanic District of Slieve Gullion," says:—Slieve Gullion, about 1,900 feet high, is mainly composed of Plutonic rocks that rise through the slate. This Granite is not in the main intrusive, but is rather the result of the metamorphism of the Lower Silurian sedimentary rocks. The transition from the latter to the former may be observed in many places, the Silurian rocks becoming indurated, then schistose and slightly micacised, passing into Crystalline Gneiss, which frequently loses its foliation and passes into Granite. In the huge dyke protrusion from the igneous mass of Slieve Gullion at the eastern end, its volcanic character can be well seen, while at its Western end it can scarcely be distinguished from the adjacent Granite. In Tyrone County, Mr. Nolan remarks that at Fir Mountain we find Micaceous Schists and foliated Gneiss, passing into Granite and Syenite.

In a most valuable paper on the Geology of part of County Donegal, Professor A. H. Green, F.G.S., speaking of a section to the East of the Quartz rock of Errigal, says:—I would wish then to lay stress on the following facts. The interstratification with Mica Schists of beds of rock which can hardly if at all be distinguished from Granite; the very gradual passage from alternations of of Granitic Gneiss and Mica Schists into Granite alone; and the marked traces of bedding, and other signs of stratification that appear in the last. Mr. Green considers we have here an undoubted instance of metamorphic Granite. In the discussion which followed the reading of this paper, exception was taken to the section

Granites of Norway. Sir Charles Lyell says that David Forbes had ascertained that the free quartz in trachytes, which are known to have flowed as lava, has the same specific gravity as the ordinary quartz of Granite. I have, however, not been able to alight upon Forbes's paper, but I find that G. Jenzsch (Pogg. cxxvi., 497) discovered an amorphous form of silica in the porphyry of Regensberg, with specific gravity 2·620; and that the mineral Vestan, which is pure silica, occuring in triclinic crystals, and which is found in the igneous rocks of Saxony and neighbourhood, has also a specific gravity of 2·65, or the same as ordinary quartz. The second objection urged by Dr. Haughton does not seem to be of any great importance, and in fact the reverend Professor does not rely very much on it when arriving at the conclusion that Granite, though sometimes a Pyrometamorphic, is more generally a Hydrometamorphic rock.

In bringing these various facts and opinions of observers and philosophers together, I have endeavoured, as far as possible, to give you an unbiassed statement. For my own part I believe here, as in almost every path of natural science, we are groping our way in a dimly lighted road. "More light! more light!" is the cry of the philosopher. The following points seem, however, to be fairly established:—

1st. That there are the closest possible relations between Granites and purely volcanic rocks, and that every gradation can be shown from the one to the other.

2nd. That no fact has *yet* been observed which can be used as a conclusive argument against the purely Igneous origin of Granite.

The metamorphic origin of certain Granites seems to be as yet an open question. It would appear to me to be perfectly possible that originally sedimentary rocks of

great age, under the combined influences of the interior heat of the earth, pressure, and water, might assume a crystalline structure without being fused, and we thus obtain a metamorphic Granite. The examination of the great mass of Archæan rocks on the American continent may, perhaps, elucidate this question.

Undoubtedly, however, the larger proportion of the Granitic masses which now form part of the earth's interior, have been in a state of fusion. How were they fused, and from what materials have they been derived? Are we to believe, with Mallet, Thomson, Hopkins, and others, in a vastly thickened crust, or are we, with others, to think that the increased temperature noticed on descending into the earth's interior continues unabated till we soon reach a reservoir of material at such a temperature that, under conditions similar to those which obtain at the surface of the earth, would be sufficient to melt the most intractable substances? Is it possible astronomical mathematicians have omitted some important factor in the calculations of the "thickened crust?" The researches of Prof. Newcombe into Vortex motion may well make us cautious in dogmatising too strongly with reference to planetary bodies. Whichever theory be true we may still respect the believers of both, and admire the many points brought forward on either side. Our necessarily imperfect knowledge enables our imagination to lead us frequently astray! But, after all, though the charm and beauty of a theory are only secondary matters, we look with almost unabated delight to the old writers, albeit we know their scientific conclusions were sometimes entirely erroneous. We still admire the sublime conceptions of Milton as to the beginnings of this earth of ours, though convinced of their scientific inaccuracy. We still, despite his ignorance

and had the rock below been an ordinary Granite we should have been almost justified, from the evidence, in assuming that we have the different stages from a sedimentary rock to a truly intrusive Granite. But, although we know now that the action of a mass of heated rock below may so completely change the character and appearance of an overlying sedimentary rock, we see clearly that even when we seem to have gradations from one class of rock to another, it behoves us to exercise the greatest caution in drawing deductions therefrom. Is it not possible that in those districts of Ireland where we hear of the same Granitic mass being at some places Intrusive and at others Metamorphic, that we have a somewhat similar set of conditions to that at Schuttrisberg; only instead of the heated mass below being absolutely different from, it is closely allied to that above in mineralogical and chemical composition?

Professor Ramsay says in his "Physical Geology and Geography of Great Britain," in one sense Granite is an igneous rock; that is to say, much of it has often been completely fused, but in another it is often a metaphoric rock, because it is sometimes impossible to draw any definite line between Gneiss and Granite. Proceeding on the arguments that there is generally a quantity of free silica, and that the felspar and mica crystallised before the quartz, he arrives at the conclusion that the quartz was probably held in partial solution in hot water even after crystallisation by segregation of the other minerals had begun. After closely examining the works of Cotta, Bischoff, and others as to the grounds of the assumption that the quartz was always the last mineral that crystallised out, and testing the Granites of Cornwall, I was led to the conclusion that here at least there were Granites of which the quartz was undoubtedly the first

mineral that crystallised. As I described my views and the reasons thereof in my paper read before this Society, I will not again weary you with them. It was, I need hardly say, with great pleasure that I afterwards read in Professor Judd's description of the rocks of the Ponza Islands, that he had noticed also other Granites in which the quartz was the first mineral to crystallise.

H. C. Sorby (*Mineralogical Magazine, Nov., 1876*), reasoning from the remarkable experiments of Caignard de la Tour, suggests that in the cooling down of the heated rock the quartz was mainly if not entirely formed when the temperature of the rock had fallen just below the critical point of water; that is to say, that it began to crystallise as soon as the partially melted mass could be exposed to the solvent action of liquid water. The anhydrous Felspars crystallising first caught up steam, but the quartz liquid water saturated with soluble salts.

The Rev. Professor Haughton shows that in the Felspar Porphyry of Forkhill, County Armagh, and Granite of Slieve Corragh, County Down, the quartz first crystallised out. This cannot therefore be used as an argument against the igneous origin of Granite, and Dr. Haughton,* whose papers on the Granite question are of the highest possible value, bases his objections to this theory principally—1st. On the specific gravity of the quartz in Granite being 2·6, or the same as that when this mineral has formed from aqueous solution. 2nd. To the actual presence of large quantities of water in the Mica of the Granites of Leinster, and of minerals which rapidly change their character on ignition in the

* "Dr. Haughton, whose fertile mind seems to have infinite resource, has also dealt with the question of the Crystallisation of Fused Rocks on the principle of least Paste." See Trans: R. I. Academy, Vol. xxvi. All students should read this.

given by the author; and Mr. David Forbes mentioned that the Granite not only sends out veins into the surrounding rock, but also encloses fragments of the rocks through which it passes. This latter observation is confirmed in a paper by W. Harte, C.E., and also by R. H. Scott, M.A.

With regard to the Granitic and Syenitic rocks of Charnwood Forest and its vicinity, which Dr. Holl (in the Pre-Cambrian Rocks of Central England.—British Association Reports, 1865) seems to think shew traces of stratification, I think there can be no doubt, after reading the description of the beds of Volcanic Ash, Porphyritic Dykes, &c., by later observers, that in this district too, we meet with undoubted evidences of volcanic activity, and that these Granitic rocks are related to those whose volcanic origin is allowed by all. Messrs. Hill and Bonney, Quarterly Journal of Geological Society, Vol. 34, p. 223—first pointed out the dyke of Diorite on the western side of the Granitic mass of Brazil Wood, hard by Mount Sorrel, and Messrs. S. Allport, F.G.S., and W. James Harrison, F.G.S., in a most interesting paper, show that the Granite is clearly intrusive in the Gneiss of Brazil Wood, and the latter rock is probably the result of the alteration of Clay slates. In one excavation they noticed that the Granitic vein encloses a lenticular piece of the metamorphic rock, 3 feet by 2 feet. W. J. Harrison, in his Geology of Leicestershire, clearly points out that the masses of Syenite, &c., when traced on the surface appear everywhere as rounded bosses or knolls, but possessing no definite line of extension or strike, which if they truly alternate with the slates they should have. Instead of this they stand everywhere as islands in the sea of slate, and have all the appearance of having been deeply seated igneous masses exposed by

denudation. Since this was published, in fact quite recently, a microscopic examination of the Leicestershire Gneiss was made, and its character was found to be similar to that of gneissic rocks observed around large masses of Granite; thus affording another example of contact metamorphism. Now, we find examination in the field has confirmed the generalization. Having, fortunately, had some little experience with Mr. Harrison in the laboratory and in the field (though in another district) I feel no hesitation in bringing forward his discoveries with full confidence of their scientific accuracy.

A most fortunate example in relation to the action of Granitic on Sedimentary rocks is to be seen at Schuttrisberg. A crystalline rock, known as Aplite, composed of Orthoclase and Quartz, to which Hornblende, Tourmaline, and other minerals are sometimes added, occurs at the junction of the Syenite and Gneiss.

"Microscopic and chemical examination alike demonstrate conclusively that Aplite cannot possibly be regarded as an intermediate stage between Gneiss and Syenite. Of the former it certainly represents the last stage of alteration, but with the latter it has absolutely nothing in common. It is a rock of far more acid composition, and it contains much free Quartz and Orthoclase Felspar; while the igneous masses in contact with it have little or no Quartz, and the Felspar is principally plagioclase. The particles must have attained the condition of absolute internal mobility, as shown by the nearly perfectly crystalline character of the rock, and that as a consequence of this the mass was in a truly plastic state, is shown by the fact that it was capable of being injected in the form of veins into the fissures of the surrounding masses." We have here a most complete change from Gneiss to Granulite or Semi Granite,

of Copernicus, love and revere grand old Addison when he exclaims, like the true lover of Nature that he was—

> "What though in solemn silence all
> Move round this dark terrestrial ball,
> What though no real voice nor sound
> Amidst their radiant orbs be found;
> In reason's ear they all rejoice,
> And utter forth a glorious voice,
> For ever singing as they shine."

ON THE CARBONIFEROUS LIMESTONE NEAR SKIPTON, AND IN NORTH DERBYSHIRE.

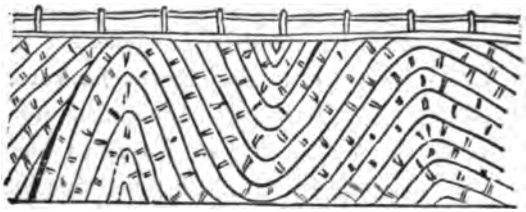
By Charles Ricketts, M.D., F.G.S.

The Carboniferous Limestone near Skipton.—The upper strata of the Carboniferous Limestone are exposed in various places along a narrow belt of country, extending in an easterly direction from Skipton to nearly as far as Bolton Abbey; they form the summit of an anticlinal, having each side flanked by Yoredale shales and superincumbent grits. This succession of hard and soft strata has had the greatest effect, not only here, but in other parts of Yorkshire and in North Derbyshire, in determining the contour of the country; the hard grits withstanding an amount of atmospheric disintegration which has readily worn away the softer shales, thus forming steep escarpments, rising from where the shaly beds pass beneath them; so that, to use the words of Profesor A. H. Green, "the base lines of the gritstone beds may often, from some commanding height, be sketched in for miles round.*"

Though the Limestone essentially forms an anticlinal, it has also experienced most remarkable contortions,

* "Memoirs of the Geological Survey." The Geology of North Derbyshire, &c., page 3.

bendings, and foldings. Along the canal bank at Skipton the beds make numerous but gentle curves; whilst in other sections visited—the quarry at the commencement of the road to Embsay, the extensive quarries at Haw Bank, those near Draughton, and at Hambleton, near Bolton Abbey—they form domes, synclinals, and anticlinals, or a series of abrupt crumplings and contortions.



CARBONIFEROUS LIMESTONE, DRAUGHTON VILLAGE.

These contortions, as well as the general anticlinal, must have originated in the same lateral pressure. It is not improbable they may have occurred as a secondary effect of subsidence taking place during the deposition of the Carboniferous shales, sandstones, and grits; the weight of their accumulation, by pressing downwards the crust of the earth, permitted the continued addition of fresh materials;* the depression thus induced must as a

* During the meeting of the British Association at Sheffield, Professor P. Martin Duncan, F.R.S., in his address as President of Section C., directed attention to "the progressive general subsidence" which occurred during the deposition of the Carboniferous strata, especially remarking that "the regularity of the subsidence and its amount must have kept pace with the thickness of the accumulating deposits." References to somewhat similar coincidences of accumulation and subsidence in other formations are constantly made by observers in Physical Geology; but no English Geologist regards these phenomena as *cause* and *effect*, though they are fully recognised as such by Americans—by Professors James Hall, Dana, Le Conte, Shaler, and others—while Captain C. E. Dutton, of the United States Ordnance Survey, states that as "few Geologists question that the great masses of sedimentary

stone, according to their state, is either eroded deeper at the cracks, or the Calcite stands out slightly in relief. The surface is also hollowed in small irregular pits, similar to those formed by the growth on Limestone of moss, or other lowly organised vegetable. Upon this surface lies a thin layer or film of carbonaceous matter in a bed of yellow clay about an inch thick, covered and filled with small fragments of Limestone; some of these fragments are decidedly weathered, others are angular, but none had any appearance of recent fracture. In a joint, passing downwards through the Limestone bed, a similar process of weathering of its sides has taken place, and an extension from the Clay bed fills the joint. Below this bed several cavities (miniature caverns) have been formed in the Limestone at different levels, exposed as low as fifteen feet below the eroded surface, and are filled with a similar Clay, but it could not be determined whether any channels extended to them from the bed of Clay above. On submergence taking place Limestone was again deposited over the Clay, &c.

Professor Green states that at the mouth of the railway tunnel, near Buxton, the surface of the Limestone on which the Toadstone rests is very much waterworn, and considers that this may be because the top of the Limestone was a land surface before the Toadstone was deposited.*

Other examples of such Islands, formed by the uplifting of the Carboniferous sea-bottom, are met with farther north. Professor John Phillips, in a report on the probability of the occurence of Coal near Lancaster (1837), referred to the existence of traces of thin beds of Coal in the Scar Limestone at Kellet, and near Kirkby

* "Geology of North Derbyshire," p. 20.

Lonsdale, but did not mention under what circumstances they were formed. Three examples of the occurrence of thin beds of coal, lying in a similar manner to this in Ashwood Dale, on weathered and eroded surfaces of the Carboniferous Limestone, were brought before the notice of the Society during the Session of 1877-78, but a description of them was not recorded in the Proceedings; they occur at Ingleton quarry, in a roadside quarry at Hendridden, 4½ miles north-east of Carnforth, and in the Silverdale Limestone quarry.

THE GLACIAL BEDS OF THE CLYDE AND FORTH.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

Since Smith, of Jordanhill, first drew attention to the laminated Clays of the Clyde, and, assisted by Edward Forbes, established their Glacial characteristics, the Clyde basin has been classic ground to Glacial Geologists.* When so many eminent and painstaking Scotch Geologists have devoted so much attention to the evidences existing all over their country of the former prevalence of an Arctic climate, I fancy I hear it asked, "What can a stranger, after a week or two's examination, have new to say on so old a subject?"

In working out the Drift deposits of the north-west of England, I felt strongly that no decision of permanent value could be come to without an examination of the contiguous deposits in Scotland and those in Ireland. The latter I examined last year, and gave you some of the results of my investigations, which you thought

* "Researches in Newer Pliocene" and "Post-Tertiary Geology."

into the Yellow Sea in 33° north latitude, so altered its course that its waters now pass into the Gulf of Pee-chee-lee in 37½° N.; the two outlets being separated from each other by the mountainous district of Shan Tung, or East Mountain, and by a distance, measured along the coast line, of not less than 640 miles.* This was not the first time such a diversion of the course of this great river occurred. The effect must be to produce Geological changes comparable in magnitude, and to a considerable extent in effect, with those which took place subsequent to the strictly marine deposit represented by the Carboniferous Limestone.

TOADSTONE.—The Volcanic rocks, locally known as Toadstone, occur on different horizons; they consist generally of Lava flows, and are mostly vesicular; the vesicles being filled with Calcite, or in the upper beds, as before remarked, with Calcite and crystals of Quartz. The base of these Volcanic rocks was only observed at Diamond Hill near Miller's Dale Station, and at the junction of Cressbrook Dale with Monsal Dale, both probably being on the same horizon. The latter locality presented an interesting section consisting of—

Limestone.

5. Vesicular Lava (Toadstone), 12 feet and upwards.
4. Calcareous Vesicular Lava, 1 foot.
3. Light green Ash, 8 inches.
2. Vesicular Lava (Toadstone), 3 feet.
1. Calcareous Volcanic Ash and Bombs, 4 inches.

Limestone.

Upon exposing fragments of the lowest bed (1) to the action of acid, it was found that the undissolved portion, amounting to 31 per cent., consists of

* "Geographical Magazine," April, 1878.

fine Volcanic ash and small Volcanic bombs. The bed above it (2) is similar to the Toadstone generally. The fine green Ash (3) contains no calcareous matter. The thin bed of Lava (4), when the carbonate of Lime has been dissolved out by an acid, has an appearance something like pumice and differs considerably from beds 2 and 5, which resemble ordinary Toadstone. No convenient opportunity was afforded of determining the thickness of 5.

The junction of the upper surface of the Toadstone with the Limestone can be traced for considerable distances on different horizons, and nowhere was any change observed affecting the overlying limestone.*

At the foot of the lofty perpendicular escarpment of Rancher Tor, the surface of the Toadstone is irregular, and forms hollows into which the limestone, there distinctly banded, curves and fills. The evidence is therefore sufficient that these Volcanic rocks were formed by the eruption of Lava, and sometimes of ashes, over the bed of the Carboniferous Sea.

Low Islands in the Carboniferous Sea.—At a distance of three miles from Buxton, where Deep Dale joins Ashwood Dale, one of the beds in a quarry in the Lower Limestone has its upper surface whitened, the weathering extending for some distance into the rock, and is covered with a white powder as well as minute sub-angular fragments of Limestone; casts of Producti covered with a carbonaceous film lie upon the surface; shrinkage cracks are abundant, some remaining unclosed, whilst others are sealed with Calcite; they must have occurred previous to the weathering, for the Lime-

* Specimens of Limestone resting on Toadstone, obtained at Rancher Tor and on the banks of the river to the west of Miller's Dale Station, afforded a large amount (3½ to 5 per cent.) of sponge spicules.

necessary consequence of the globular form of the earth have squeezed these strata when deep-seated, into a less *lateral* space, causing in them contortions and convolutions; inasmuch as the chord of an arc is less than its circumference.

THE CARBONIFEROUS LIMESTONE OF NORTH DERBYSHIRE.—Attention was more particularly directed to the difference in the mineral composition of the middle beds of the Limestone, compared with the upper. In Miller's Dale the former, for a thickness, according to Professor Green, of 820 to 900 feet, consist of massive beds without the admixture of foreign materials, nor is there shale or, as a rule, other substance between the divisions of the beds; the chief exception being the Volcanic rocks locally known as Toadstone. Above these, for about 390 feet (Green), the beds become cherty, the chert sometimes occurring in the form of concretions and nodules, or is interstratified with the Limestone; whilst in some localities the fossils have to a great extent had the calcareous matter which originally formed the shells replaced by silica. At Bakewell the Toadstone, there interbedded with the Upper Limestone, has its vesicular cavities partially filled with quartz crystals, along with Calcite.

A great change must have occurred in the composition of the sea-water contained in the great Carboniferous Bay of the North-West of England, in which this Limestone was deposited, to permit the addition of these siliceous materials in an area where no such extraneous

deposits displace the earth beneath them and subside, surely the inverse aspect of the problem is *à priori* equally palpable; that those regions which have suffered the greatest amount of denudation have been elevated most; thereby assuming the removal of strata as a cause, and the uplifting as the effect." ("The Geological History of the Colorado River and Plateaus"—*Nature*, Jan. 16th, 1879.)

substance previously existed. As the deposit of the Carboniferous Limestone continued to progress, the general effect here, in North Wales, and elsewhere, was for it to become more impure, for its beds to become thinner; and carbonaceous and other shales were interstratified with them, until its termination was determined by the overwhelming of the whole area by the mud, the siliceous sands and grits, and the beds of coal represented in the Yoredales, the Millstone Grit, and the Coal-measures.

What was the nature of this change, and how was it produced? In a communication made to this Society during the Session of 1875–76, with the intention of illustrating from a consideration of the Carboniferous formation the dependence of subsidence of strata upon the weight, and that its progress is in accordance with the amount of accumulations,* it was suggested that the Yoredales and other Upper Carboniferous rocks have resulted from the subsidence, which occurred during the deposition of the Limestone, persisting until a ridge, previously dividing from this area the channel of a large river, had sunk below the sea-level and allowed the course of the stream to be diverted into it, bringing down débris from the disintegration of far distant Granitic or Granitoid mountains, in the shape of mud, sand, and pebbles, the depression necessary to allow this deposition still going on in accordance with the amount of deposition. The chances are very great against a phenomenon similar to that here supposed occurring amongst the large rivers of the earth, even during many generations; but one somewhat like it happened in China during 1852–53, whereby the Whang Ho, or Yellow River, formerly emptying itself

* "Remarks on the Country around the Wrekin," by Charles Ricketts.—Proc. Liverpool Geol. Soc., part 2, vol. iii., p. 113.

worth publishing in the last Transactions of the Society;* also I contributed a short paper "On a Section of Drift near Ballygally Head" to the Geological Society of London.† I merely mention these facts to explain that the whole of my contributions on the subject, though appearing in detached papers, are really a connected series of observations.

Through the kindness of Mr. David Robertson, F.G.S.—than whom no one has a fuller acquaintance with the Glacial deposits of the Clyde—I was supplied with information as to the typical localities in which to view the sections now exposed. To Mr. Dugald Bell, late Secretary to the Glasgow Geological Society, I am also indebted for much information and assistance; and, lastly, to Mr. Robert Craig, of Beith, I owe an acquaintance with some of the most important facts I purpose laying before you to-night.

The Rivers Clyde and Forth traverse, the one in a westerly, the other in an easterly direction, strata from the Old Red Sandstone to the Coal-measures, inclusive, which strata have been preserved in the midst of much older rocks through being let down in a trough by two faults, the one extending from the Frith of Clyde to Stonehaven, the other from Girvan to Dunbar. As shewing how the Geological structure of a country affects its inhabitants, it is very striking to a stranger to find the principal industries of Scotland confined to this area of about 5,000 square miles.

Upon these rocks rests a covering of a strong unstratified Boulder-clay, called by the Scotch Geologists "Till," of varying thicknesses, in some cases absent

---

* "Notes on the Scenery and Geology of Ireland."—Proceedings of Liverpool Geological Society, Session 1878–9.

† Quarterly Journal of Geological Society, vol. xxxv., pp. 679–681.

altogether, but more especially developed in the lower part of the river basins; and upon this deposit rests one of an entirely different physical constitution, viz., the laminated shelly brick clays of the Clyde and Forth.

It is true that some of the Scotch Geologists consider that there are two Boulder-clays or Tills, "an upper" and "a lower," with "interglacial" beds between; but for the purposes of this paper it is better to view the beds in the broad division I have given—as, indeed, it is the aspect in which they appear to a stranger—and to reserve a discussion of those refinements of sub-division until I have described the sections I have seen.

The first section I examined was not far from Mr. Bell's house at Lansdowne Crescent, Glasgow. The Till here forms a steep ridge, and is considerably above the river level. The normal colour of the clay is of a blue black, but for about 5 feet below the surface it appears to weather of a reddish brown, with blue facings on the joints. There were evidently a great number of stones in the clay; but as the hard ones had been picked out and broken for macadam, it was not possible to arrive at a correct estimate of the actual quantity or relative proportions of the stones. Mr. Bell says the surface slope is generally to the east gradual, to the west steep. The knoll on which the Glasgow University stands—a picturesque group of Gothic buildings, in a commanding position—is of a similar Till; and these knolls, Mr. Bell also says, bear no relation to the rocks below. In the University Museum is a very fine collection of stones from the Till of the excavations, made by Mr. John Young, of the same general character as the collection kindly made for me from the Stobcross railway cutting on the north shore of the Clyde, 50 feet above sea level, by Mr. David Robertson, F.G.S., and Mr. Bell,

in 1874, a portion of which I exhibit. The contained stones are mostly local Carboniferous Sandstones and travelled stones from the West Highlands. The travel of the Drift, from whatever cause, has here apparently been up the Clyde Valley.*

The next section of Till I examined was on the cricket ground near the Deaf and Dumb Institution at Crosshill, near Glasgow. The excavations were being made for the purpose of dressing off the sides of the knoll smooth. The Till was very full of stones, a large proportion being West Highland rocks. It is blue black in colour, and very hard and intractable, even to the pick. The stones varied in size from 3 ft. 6 in. long to small pebbles. There were angular, sub-angular; and rounded boulders, and smooth water-worn pebbles, as also angular pebbles. Many of the stones were striated, but as a rule not so intensely as those in our own marine Boulder-clays. The largest proportion of the rocks are undoubtedly local Carboniferous Sandstones and Limestones. On one side of the slope of the knoll lies a patch of clay with but few stones in it, somewhat resembling our marine clays; it may be the wash of the hill. At the foot of the knoll is a bed of siliceous sand of a rich yellow or brown colour, similar to the surface sand about here, which I have named "Washed Drift Sand." The following is the Section. (See Section Sheet, Fig. I.)

ROCK.

a. Surface soil.
b. Reddish brown plastic Clay, with few stones.
c. Brown Clay, with blue facings.
d. Very stony Till.

---

* This is not so remarkable as it seems at first sight. If we examine the map, we find that all the lochs opening into the River Clyde trend to the south-west. Loch Lomond has the same direction. The striations I observed were also south-west. The contours of the country evidently determined the direction in this case.

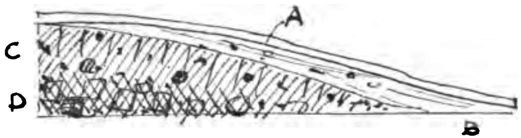
PLATE I

GLACIAL BEDS OF THE CLYDE AND FORTH

TVR

CRICKET GROUND
CROSSHILL

FIG 1



GREENHILL QUARRY
KILMAURS

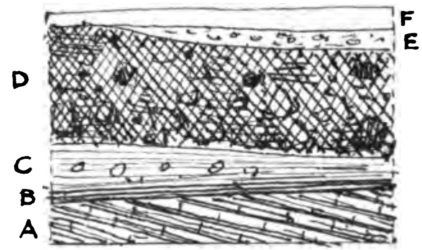


FIG 3

CARTSDYKE DOCK
GREENOCK N. SIDE
FIG 2

1880

The next Section I examined was at Seedshill Quarry, Paisley, in the company of Mr. Robert Craig.

The surface of the ground is here about 40 feet above the level of the river at high water. The surface of the rock (dolerite) below the Till is smoothed and striated N.W. by W., with, Mr. Craig says, cross striations N.E. The Till is very hard, of a purple black colour, and has to be blasted with dynamite; it contains at the bottom many stones of the bed rock, and fully half the Till is composed of stones large and small. Upon the Till under the surface soil is a bed of reddish brown clay; apparently reconstructed from the clay below. At another point in the quarry the lower part of the Till is of a gravelly nature, and where this occurs Mr. Craig informs me the rock beneath is rougher and less striated.

Mr. Craig then took me to see the brick pits about Paisley, which are excavated in the laminated fossiliferous clay. Among others we inspected the Victoria Tile Works. The total depth to the surface of the Till, upon which the bed of brick clay lies, is about 22 feet. The shell-bearing bed lies directly upon the Till, and is about two feet thick. Above this is about 15 feet of brick clay of a dark purple colour, and over this a surface bed of sand and gravel about five feet thick. The brick clay is of a very fine unctuous nature, and has shells sparsely distributed through the mass, also boulders, often with *balani* upon them, and there are also pebbles. These stones are quite isolated objects embedded in the clay, which is evidently a deposit of very fine argillaceous mud. The shell-bearing beds are avoided by the brickmakers as not suitable to their purpose.

The laminated brick clay evidently rests on an eroded, uneven surface of the Till, and is quite of a different character to our marine Boulder-clays, which are much

more stony and contain more evidences of the prevalence of a Glacial climate. This being my first introduction to these beds, I was very much interested, although, unfortunately, it was raining the whole time.

From Paisley we took the rail to Greenock, and examined the excavations of the new Cartsdyke Dock. The following is one of the sections on the north side:—(See Section Sheet.)

A. Old Red Sandstone.
B. Broken Do. and Red Sand.
C. Till.
D. Shelly band of the laminated clay lying on Red Sand. "*Cyprinæ*" plentiful.
E. Laminated brick clay of a reddish brown hue.

There was also under the Till at another spot a striated surface exposed, direction N.W. and S.E., on a grey coloured rock, a member of the Old Red Sandstone.*

On the south side of the dock was another section, shewing 14 feet of Till resting upon a bed of Red Sand lying on a broken surface of Old Red Sandstone. The Till is harder than our marine clay, but intermediate between it and the typical Till.

The great interest of these sections, to me, lay in the fact of the Till lying upon rocks of a nature approaching our New Red, and in finding the phenomenon of the Red Sand—the broken rock between the clay and the rock—precisely as we find it about here, while it is absent on the glaciated surfaces.†

* I am informed that the Geological Survey has now relegated these sandstones to the "Calciferous Slates."

† See Section in Quarterly Journal of Geological Society, vol. xxx., pp. 27-28, bed No. 3.—Taking for granted, at the time, that the Scotch Till was, as considered by eminent Scotch Geologists, "ground moraine," I then thought this Red Sand was its equivalent. Further on it will be seen I have had occasion to change this opinion, and consider the lower part, if not all, of the marine Boulder-clay synchronous with the Scotch Till.

The next locality we visited was Kilmaurs, near Kilmarnock, in Ayrshire, celebrated for the discovery, in 1816, of the remains of the Mammoth and Reindeer, which Dr. James Bryce, in 1865, after a careful examination of the Woodhill Quarry, where these remains were found, concluded had been obtained from a thin bed underlying the Till and resting on the Carboniferous Sandstone.* The Woodhill Quarry is now closed, but there is another open, not far off in the same valley, called Greenhill Quarry, and this Mr. Craig kindly took me to see. A sketch of the section exposed is given in the Lithographed Sheet, Fig. 3.

A. Carboniferous flagstones (dip about 10° S.)
B. Do. underclay.
C. Till, composed largely of underclay.
D. Hard Till.
E. Gravel.
F. Subsoil clay.
G. Surface soil.

At a Quarry about 200 yards higher up the valley a bed of Sand about 1 foot 6 inches thick occurred, containing Arctic Shells, similar to those of the Clyde Brick Clays, and under it was a bed of Peat, from which Reindeer's horns and Mammoth tusks were taken. The Clay is described as a soft Till, and was believed by some to be an "upper" Till. This bed of sand with shells Mr. Craig says he has proved, by various coal pit sinkings, extends parallel to the Railway as far as Kilmarnock, and varies from 2 to 5 feet thick. It is only a narrow patch. The Till on the higher levels is 90 feet thick; in the valleys 40 feet. Two fragments of *Astarte* were found in the Till, about 40 feet from the bottom, in one of the pit sinkings.

* "On the occurrence of Beds in the West of Scotland beneath the Boulder-clay."—Quarterly Journal of Geological Society, vol. xxi., p. 213.

There is a bed of sand at Kilmarnock lying on the Till, from 20 to 30 feet thick. It contains small stones, but no shells.*

One of the noticeable objects between Paisley and Kilmarnock is Kilbirnie Lake, near Beith. It is 90 feet deep, and 4½ miles long, by from 1 to 1½ miles wide. It is a hollow in the Till, the outlet being over rocks at the north end, which accounts for its not being emptied by the cutting down of the outlet.

In sinking some colliery pits at the "Homes of Garnock" about from 20 to 30 feet of mud and sand supposed to be the bed of an old lake, were passed through. The Till in the neighbourhood is from 40 to 90 feet thick.

At Beith, some of the glacial phenomena can be well studied. There are several quarries in the Carboniferous Limestone (worked for limeburning), and Mr. Craig, who has been familiar with them from his youth, and is a keen and truthful observer, pointed out to me some of the more remarkable features. At the Broadstone Quarry the upper beds are broken, cut into, and dissevered, as shown in the sections, detached pieces of rock, evidently displaced, but resting on the bed rock underlie the Till which fills up the whole of the irregularities, making a smooth surface contour to the hill. As well as the detached blocks there are limestone boulders, and other boulders and pebbles, in the Till. Before the Till was laid down, the upper strata of limestone, coal bands and shale appear as if subjected to some disruptive force.

At the Hill Head Quarry there are striations on the

---

* A good deal of detailed information respecting these beds will be found in a paper by Messrs. Young and Craig in the "Transactions of the Geological Society of Glasgow, vol. iii., part ii., p. 310."

.ATE 2

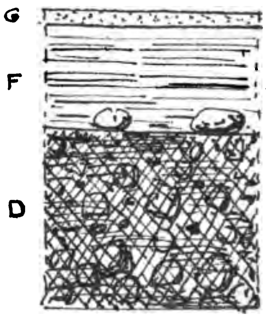
GLACIAL BEDS OF THE CLYDE AND FORTH

TVR

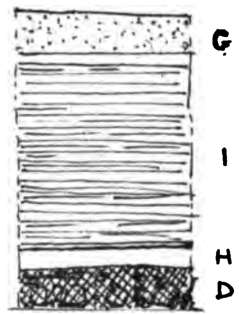
BROADSTONE QUARRY BEITH

A Carboniferous Limestone B Coal band. C Disrupted bed of Limestone D Till E Surface soil –

LEITH DOCKS



D TILL
F SHORE SAND
G D°. SURFACE BED
H SHELL BED
I DARK PURPLE BRICK CLAY
D' GRAVEL



1880

limestone, below about 7 feet of Till, in a direction N.N.E. There are also three bands of chert, A B C, lying irregularly upon each other (6 to 9 inches apart), which Mr. Craig informs me he has traced in another place close to, where there are in the aggregate from 12 feet to 15 feet of limestone between them. His theory is that the limestone has been dissolved out by rain water until the insoluble chert bands became directly superimposed on each other, and that as they show no signs of other displacement this must have happened since the Glacial period. Upon it he has founded an estimate of Geological Time,* which is ingenious and worthy of attention.

After this examination of the deposits on the west side of Scotland, I took the rail to Edinburgh, and had the good fortune to see an excellent section of the Till in the New Leith Docks. I produce sample, which is more like rock than clay. It is of a deep blue-black colour, closely packed with stones, many being of dolerite. Some of the sandstones and limestones are striated, but many of the stones are quite angular, and I noticed that they do not lie in any regular position, but many of them have their axes vertical, more especially the smaller ones. Numbers of the stones are rounded, waterworn, and unstriated. The Till is more compact and stony than that at Greenock. The materials appear to have been principally derived from the Carboniferous rocks.*

There are brick clays in the neighbourhood similar to those of the Clyde, but I saw very little of them.

The next place I visited was Elie, in Fifeshire, with

* "Geological Magazine, 1878, pp. 479—80.

* In some borings at Leith the Till was found to descend some 100 feet below the sea level. See paper "On the Phenomena of the Glacial Drift," by A. Geikie.—Trans. of Geo. Soc. of Glasgow, vol. i., part ii., p. 42.

the object of seeing the Arctic shell clays, described by the Rev. Thomas Brown.*

The visit was a decidedly unsatisfactory one, but from what I saw and the description given, the beds seem to occupy the same Geological postion as the Clyde Beds, though the *facies* of the shells is of a more Arctic character.

I followed up one of the burns a long way inland, bnt all I could discover was a general mantle of Till overlaid near the burn by river alluvium. In places on the road-side is to be seen a bed of sand overlying the Till, and this seems to be general. Probably it is subaërial.

St. Andrew's formed my resting-place after these little Geological excursions. The only thing bearing upon the subject of my paper I noticed there was a raised beach, apparently resting upon estuarine mud; probably this may be on the Geological horizon of the raised estuarine deposits of the Tay.

To sum up my conclusions, which I will do very briefly, the conviction has been slowly forcing itself upon me that there has been a tendency to unnecessarily complicate these Glacial phenomena—to raise every gravel bed into a "formation," or bed of sand into a "period;" while "interglacial" episodes are profusely scattered through the whole, apparently with the sole object of finding out what Mr. Croll theoretically says "must have happened."

Looking at the subject in its broad divisions, the conclusion I have come to is that the Scotch Till is the Geological equivalent of the lower part, if not the whole, of our marine Boulder-clays and sands. That, in fact, as the land subsided the materials brought down by glaciers were scattered over the sea bottom in distant localities,

* Trans. Royal Soc. of Edinburgh, vol. xxiv., pp. 617—633.

forming our marine Boulder-clays; while nearer their source, in front of and probably *under* the glaciers, while in a state of semi-flotation, the unfossiliferous Till was formed. This is, in the nature of things, what would happen. The stones and heavier materials would be shed more profusely near to the land, while the finer materials would be taken further out and deposited in the sea.

Immediately on coming back I examined the brick pits at Walton Lane Station, and was much struck with the justness of this explanation of the phenomena which occurred to me when in Scotland. I also observed that at Greenock the Till approached more nearly to our marine clays, though still "Till."

I must confess I cannot see my way to the conclusion so generally prevalent that the Till is wholly subaërial and formed under land ice. It seems to me most unphilosophical first of all to attribute the planeing, grooving, smoothing, and striating of the whole surface of the land to ice, and then to make the very same agent, without any apparent reason for the change, deposit a mass of Till in the same places, in many cases over 100 feet and sometimes reaching 162 feet thick.* It also appears to me incomprehensible that all the fine material forming the bulk of the clay matrix should remain under land ice having a general drainage to the sea. It is certainly upon upholders of this theory that the onus of proof lies, and though I have read many books and papers on the subject, I have never seen anything more than a general statement that there is a "moraine profonde" answering to the Till found under glaciers now. This statement, to my knowledge, has never been proved. If, however,

* "On the Phenomena of the Glacial Drift of Scotland." A. Geikie. —Transactions of Geological Society of Glasgow, vol. i., part 2, p. 42.

we admit (what is probably true) that there first of all existed an ice sheet or confluent glacier, extending from the mountainous districts of Great Britain to a considerable radius around, constituting the agent which has produced the smoothings and striations we find even in our own comparatively level country, we can readily see that as the land subsided (which is about the best proved fact in Glacial Geology) the ice would, whether in the form of separate or confluent glaciers, as it entered the sea, have its weight on the bottom diminished in proportion to the depth of the water or hydraulic head outside, until, the flotation power became sufficient to break off icebergs therefrom. It is also conceivable that the finer materials of the Till might remain in the deposit under the glacier while there was a head of water outside and very little current. The stones would be deposited and remain in greater profusion under the glaciers, and they would necessarily be mostly of a local character.

It will probably be asked, if the Till was mainly formed under and in front of the ice, graduating in fact into our marine beds,* and therefore below the sea level, how can

* A very interesting Boulder-clay with broken shells, answering exactly to our marine Boulder-clay, was discovered by Mr. Robert L. Jack, F.G.S., in the lower valley of the river Endrick, near Loch Lomond, and the Caithness Boulder-clay with broken shells, described by Jamieson, is evidently of the same nature. Mr. Jack, after describing the shelly Till as resting on the rock, says:—"It is probable that further to the south-east the shelly Till may shade into the 'true Old Boulder-clay;' and I confess that but for the shelly fragments of the one I should be unable to distinguish it from the other. On the other hand, it may be that the remains of a 'true Old Boulder-clay' will be found to underlie the shelly Till; but I have not yet recognised them here. I believe, nevertheless, on grounds to be presently stated, that the shelly Till has its place *above* the Old Boulder-clay."—Trans. of the Geol. Soc. of Glasgow, vol. v., part i.

the so-called interglacial beds be explained? I think more geological significance has been attached to the presence of thin layers of peat and mud, occasionally found intercalated in the Till, than the facts themselves justify.

The bed beneath the Till at Kilmaurs, already mentioned, is classed by some glacialists as an "interglacial" bed, on what I cannot but consider very insufficient evidence; similarly those lacustrine beds, occupying depressions in the surface of the Till,* are in part classed in the same category, and by much the same process of reasoning. That there are undoubted cases of peat beds with vegetable, organic, and mammalian remains found in the Till itself I do not dispute, but they are far from frequent.

The occasional presence of marine shells in the Till is readily accounted for, without invoking great changes in climatic conditions. If the Till were formed under and in front of glaciers, a fluctuating advance or recession of the ice, occasioned by seasonal changes or cycles of temperature, such as even now obtain in glacial countries, would fully explain their occasional presence.

It is also possible there may have been fluctuations in the elevation and depression of the land during the long glacial period, instead of one continuous depression followed by a continuous elevation; in fact such fluctuating movements, as we well know by our own submerged forests and estuarine beds, occurred in post-glacial times.† A climatic change intervening, of a character insufficient

---

* A boring in the valley of the Kelvin, near New Kilpatrick, shewed 355 feet of superficial deposits. Mr. Bennie, quoted in "The Great Ice Age," p. 183.

† "Post-Glacial Geology of Lancashire and Cheshire."—Proceedings of the Liverpool Geological Society—Session 1871-2.

to be called "interglacial," would fully account for these sporadic beds, with their occasional organic contents. On the other hand, the preservation of beds of peat under the enormous sheet of *land* ice, demanded by the extreme school of glacialists, is a mechanical difficulty I wish they would address themselves to. The preservation of the vegetable matter and mammalian remains at Kilmaurs is readily understood if the marine shells occurred above them, as suggested by Mr. Young; in fact it establishes the sequence of events I have described. It is also mechanically possible that, when a glacier enters the sea, the mass of material accumulating under it may tail off and extend under it above the sea level.

The laminated brick clays apparently have no equivalent in our neighbourhood. It is evident that when they were formed there were no glaciers extending to the sea level. The stones included may all have been readily brought down by river ice. The materials also may have been of fluvatile origin, the subaërial and river denudation of the land Till would supply abundance of the fine material required; at the same time I am not denying, no less than not affirming, the existence of glaciers at the time, but I am quite prepared to believe the glacial period was fast dying out.

I have now given you as briefly as I can my impressions and inferences, and I wish it to be distinctly understood that I do not presume to dogmatise on the subject—there has been too much of that already. A simple explanation that covers the conditions of the problem always commends itself to my mind in preference to a complicated one; and if I have presumed to differ from some of those authorities who have devoted great attention to the subject, it is because their reasoning has

appeared to me to be defective—to be, in too many cases, a begging of the whole question.

The position of the so-called interglacial beds in reference to the other deposits of Till where there was really no positive evidence, has been too often assumed so as to fit into the theory advanced; while the proposition to which the land-ice theory seems to have drawn some of the extreme glacialists, viz., that our marine boulder clays have been ploughed out of sea bottoms and landed on mountain tops, is too preposterous to those who have geologically worked in the deposit, as I have, to need serious consideration.

NOTES ON HUMAN SKELETONS AND TRACES OF HUMAN WORKMANSHIP FOUND IN A CAVE AT LLANDUDNO.

By R. A. Eskrigge, F.G.S.

A small cavern on the south-eastern face of the Great Ormes Head, overhanging the town of Llandudno, has for many years been occupied as a workshop by Mr. Kendrick, the lapidary. Some weeks since, desiring to enlarge his accommodation, he commenced excavations further back into the mountain, and soon found that the cavern had formerly extended a much greater distance, and was filled up partly by stalactitic accumulations, and partly by a Limestone breccia. After working for some time in the removal of these materials, certain animal remains were found; and, carefully noting their position, Mr. Kendrick continued his excavations until below the breccia a stratum of cave earth was

reached. This earth or clay has so far only been penetrated to the depth of 2 or 3 feet, and bones and fragments of bones of some large animals have been found. The largest bone remains *in situ*. The fragments have been submitted to Prof. Boyd Dawkins, who has kindly written the accompanying memorandum. He declares them to belong to the bison, whose remains have frequently been found in similar caves. It is almost certain that further excavations will yield more remains.

The Limestone breccia succeeds to the clay, and is from 4 to 6 feet in thickness; the stones are mostly angular, and more or less cemented together by the infiltration of water through lime. In this bed about 1 foot above the clay were found portions of the skeletons of four human beings, particulars of which are given in Mr. Dawkins' memorandum. The broken tibia of one skeleton and the foot of another remain to be seen *in situ*. Associated with these, and on the same level, were found two teeth of the brown bear, bearing clear marks of human workmanship. They have been perforated and apparently used as ornaments. There are also two portions of the lower jaws of a horse, with most of the teeth entire. One of these is beautifully ornamented with a herring-bone pattern. Several boulder stones, apparently used as hand hammers, or possibly as pot-boilers, and an oyster shell much worn on one side, as if used for scraping purposes, were associated therewith. Only a small portion of one human skull has yet been found; but a lower jaw with splendid molars is in excellent preservation, and lay in close proximity to the cervical vertebræ. From 2 or 3 feet above the human skeletons were found, still in the Limestone rubble, the skull of a badger, a horse's tooth, and

remains of sheep, or goat, boar, and *Bos longifrons* or short-horned ox.

In the bones above the cave earth there is no sign of gnawing, nor of their having been split by Carnivors or by man in search of marrow. Many of the bones in the cave earth itself have been subjected to such treatment—most probably, as suggested by Professor Dawkins, broken by man himself. The extent of the cavern cannot be yet defined; a chimney-like fissure extends upwards some 25 or 30 feet. The Limestone breccia, at about the same horizon as the human remains were found, bears evidence of fire, traces of charred wood being embedded in the burnt stone. Above the breccia is a mass of stalagmite of irregular thickness, containing at different horizons accumulations of the bones of bats, mice, etc., probably brought into the cave by owls.

My first impression was that the human inhabitants of the cave had possibly been killed by the falling in of the roof; but Mr. Dawkins has no doubt, from the surrounding circumstances, that it was a place of burial. The remains still belong to Mr. Kendrick, of Llandudno, but he kindly placed them at the disposal of the writer for scientific examination, and the markings on the horse's jaw being quite unique in character, it is hoped they will be secured for exhibition in some museum. It will be seen from Professor Dawkins' notes that he considers the human and associated remains to be of Neolithic Age.*

* **August 5th.—Further excavations have since been made, resulting in the discovery of a few flint flakes, with which the markings on the horse's jaw may have been made, and also a number of small teeth with holes drilled through them, probably used as a necklace.**

MEMORANDUM ON THE REMAINS FROM THE CAVE AT THE GREAT ORMES HEAD.

By Professor Boyd Dawkins, F.R.S.

1. Remains from Cave Earth.—The broken bones are in a different mineral condition from the rest and have probably been broken by the hand of man. They consist of fragments of the marrow-containing long bones of Bison. They are, I am informed, derived from the lowest stratum, and probably belong to the Pleistocene age.

2. The Human Remains above the Cave Earth.—The human remains consist of portions of four skeletons at least—three adult and one child—and present a combination of characters similar to that determined by Professor Bush and myself in the skeletons from the sepulchral caves at Perthi Chwaren and Rhos-digre, near Ruthin, and from the chambered tomb of Tyddyn Bleidden, near Cefn, St. Asaph. Three out of the four femora are strongly carinate, and the fourth is slightly so, while the only tibia sent along with them is flattened laterally and presents the kind of platycnemism figured in my work on cave-hunting, Fig. 52, page 177.

3. The Stature of the Men Buried.—The two most perfect femora measure respectively 17·9 and 17·6 inches, which, according to Professor Humphrey's method, would imply that the average stature of their adult possessors was 5 feet 4·3 inches.

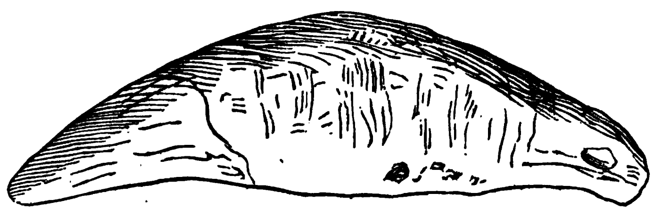
This small stature is also characteristic of the skeletons mentioned above from other burial places in Wales, and when taken along with the other characters of the bones, shews that the men who buried their dead in the cave of the Great Ormes Head, belong to the small long-headed Iberic aborigines who possessed

Europe west of the Rhine and north of the Mediterranean in the Neolithic age.

4. Associated Animals.—The remains of the associated animals belonging to the badger, brown-bear, *Bos longifrons*, short-horned ox, sheep or goat, boar, and horse, prove that the interment did not take place earlier than the Neolithic Age; while the two pendants or ear-drops, made of the right and left upper canines of the brown-bear, and the lower jaw of a horse, marked with an incised zig-zag or chevron pattern, exhibit a phase of culture more general in the Neolithic Age than afterwards.

5. The Canines of the Bear.—The upper canines of the bear have been obtained from the same head, and are ornamented with transverse lines on the fang (fig. B), and have the extreme fang perforated for sus-

FIG. B.

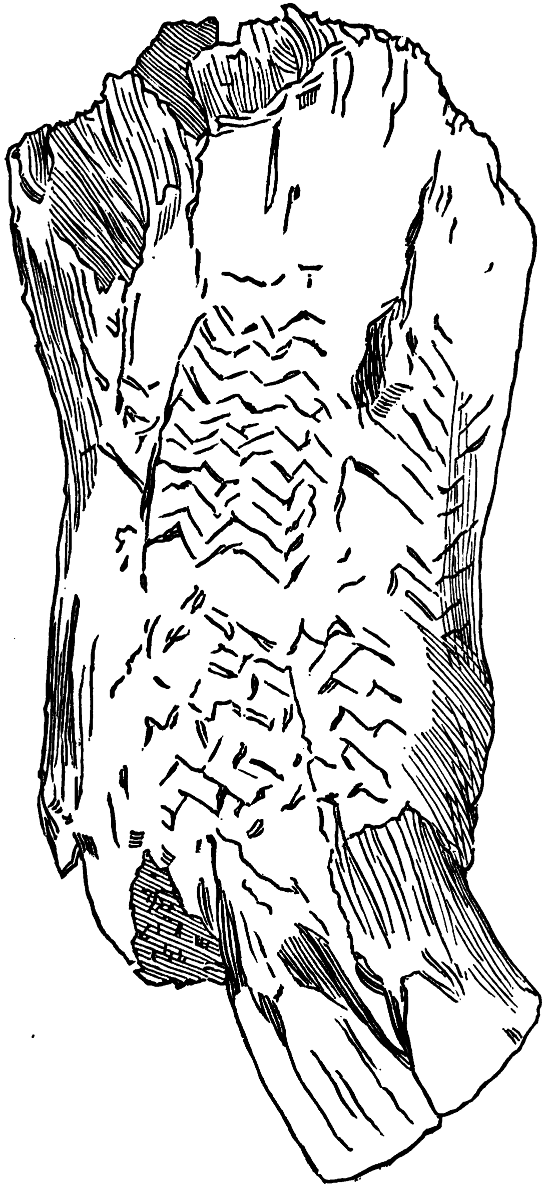


Miss Ida Thomas, *del.*

pension. From the polish on the surface it is evident they were worn for some time before they were placed with the dead.

6. Jaws of Horse, Cut and Ornamented.—The remains of horse consist of the front part of the two lower jaws, the incisors, symphysis, and the diastema broken away in front of the molar series. The outer surface of the bone has been scraped by the hand of man in both jaws, and in one it is covered with zig-zag lines (see fig. A), passing from the alveolar-edge (the edge of the

FIG. A.



MISS IDA THOMAS *del.*

diastema) on the one side, to the mental foramen on the other. In this the outer surface of the incisors is polished by friction against some soft substance, and, as it appears to me, more so than it would be naturally in the mouth of a horse. The use to which these articles were put by their possessors is altogether uncertain, but they may have been simply ornaments, or perhaps had some superstitious value.

Stones.—The stones found with the human remains are derived from the Boulder-clay of the neighbourhood, and may have been used as pot-boilers.

General Conclusion.—The general impression left on my mind by the whole series of remains is that the interment is of Neolithic age, and that the cave was used as a sepulchral vault by a family of small Iberic dwellers in the neighbourhood. The discovery is of high interest, and it should be followed up without delay.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
S. J. MACKIE, F.G.S., F.S.A., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
EDWARD W. BINNEY, F.R.S., F.G.S., Douglas, Isle of Man.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D. Sc., Queen's College, Galway.
JOHN W. JUDD, F.R.S., F.G.S., London.

MEMBERS.

ABRAHAM, J., Riverham, Grassendale Park.
87, Bold Street.
ADDISON, W. H., Deaf and Dumb Institute, Oxford Street.
ARCHER, F., B.A., Boundary Cottage, Crosby.
14, Cook Street.
BARRETT, W. S., Winton Lodge, Victoria Road, Great Crosby.
*BEASLEY, H., Acre-field House, Woolton.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
BRAMALL, H., 3, Balmoral Road.
BROWN, C. H., Low-wood, Alexandra-road, Southport.
*BROWN, J. CAMPBELL, D. Sc., F.C.S., 27, Abercromby Square.
COOGAN, P. M., C.E., 28, Green Lawn, Rock Ferry.

DAVIES, C., 8, Kinglake Street, Edge Hill.
DAWBARN, W., Elmswood, Aigburth.
The Temple, Dale Street.
DODD, J., 2, Derby Terrace, Rock Ferry.
DOWEN, Z. T., Rev., 20, Oriel Road, Bootle.
EDE, J. A., Nant Llanarmon, Mold.
*† ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackin's Hey.
FABERT, C., 3, St. James' Mount.
FITZPATRICK, M., 62, Seel Street.
FITZPATRICK, J. J., 62, Seel Street.
FOSTER, E., 7, Newstead Road, Smithdown Lane.
FOSTER, R. M., 34, Oxford Road, Waterloo.
GREEN, A., York House, Old Chester Road, Rock Ferry.
9, Canning Place.
GRIFFITHS, J., 14, Queen Street, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B., Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W.. B. Sc., 67, White Rock Street.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport,
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
KERSHAW, J., 179, Lord Street, Southport.
LEA, T., Vale Cottage, Huyton Quarry.
LEIGH-GREGSON, S., Aigburth Road.
Slater Court, 5, Castle Street.
LEWIS, J. T., 131, Park Street.
LIGHTBODY, J. H., Birchfield, Sefton Drive.
MACKINTOSH, D., F.G.S., 32, Whitford Road, Higher Tranmere.
*McCLAY, J. L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MAYER, J., F.S.A., Pennant House, Lower Bebington.
*MOORE, T. J., C.M.Z.S,L., Newsham Drive, Newsham Park.
Liverpool Museum.
*MORGAN, ALFRED 2, Rathbone Terrace, Wellington Road, Wavertree.
26, North John Street.
MORTIMER, Captain, Liverpool.
*†MORTON, G.H., F.G.S., F.R.G.S.I. (Honorary Secretary), 10, Sheil Road. 122, London Road.

†MOTT, C. G., Sunnyside, Cavendish Road, Birkenhead.
McMILLAN, A., Conway, North Wales.
PATERSON, J., Palmyra Street, Warrington.
PEARSE, W., Wellington Buildings, Chapel Walks.
Green Bank Farm, Wavertree.
*†PICTON, J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
PEARSON, J. E., Golborne Park, near Newton-le-Willows.
QUILLIAM, W. H., Rufford Road, Fairfield.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Holt Hill, Tranmere.
ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
*SEMMONS, W., 57, Gracechurch Street, London, E.C.
STONE, R., Jun., Newton Park, Newton-le-Willows.
STRONGITHARM, G., 77, Whetstone Lane, Tranmere.
SPARGO, E., Bangor, North Wales.
SHERLOCK, C., 63, South John Street.
VEEVERS, S., Huyton.
WILSON, W. H., St. Michael's Hamlet, Aigburth.
31, Wapping.
WRIGHT, B. M., F.R. Hist. Soc., 90, Great Russell Street, Bloomsbury, London.
WARD, T., Northwich, Cheshire.
WARD, J. R., 57, Garth Road, Bangor, North Wales.
YOUNG, H., 12, South Castle Street.

---

* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-SECOND.

1880-1.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART III.—VOL. IV.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1881.

OFFICERS, 1880–1.

President.

J. CAMPBELL BROWN, D.Sc., F.C.S.

Vice-President.

ISAAC ROBERTS, F.G.S.

Ex-President.

WILLIAM SEMMONS.

Honorary Treasurer.

HENRY YOUNG.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

HENRY BRAMALL.
WILLIAM HEWITT, B.Sc.
T. MELLARD READE, C.E., F.G.S.
CHARLES RICKETTS, M.D., F.G.S.
HENRY BEASLEY.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

Advocates' Library, Edinburgh.
Belfast Naturalists' Field Club.
Birkenhead Free Public Library.
Do. Literary and Scientific Club.
British Museum.
Bristol Naturalists' Society.
Bodleian Library, Oxford.
Boston Society of Natural History, U.S.
Chester Society of Natural Science.
Dudley and Midland Geological and Scientific Society.
Epping Forest and County of Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Geological Magazine."
,, "Nature."
,, "Science Gossip."
Geological Survey of Belgium.
Geological Society of Edinburgh.
Geological Society of Glasgow.
Geological Survey of India.
Geological Society of London.
Geological Society of Manchester.
Geological Survey of the United States.
Geological and Polytechnic Society of the West Riding of Yorkshire, Leeds.
Geologists' Association, London.
Glasgow Philosophical Society.
Hayden, Dr., United States.
Koninck, L. G. de., Prof., Liege.

Leeds Philosophical and Literary Society.
Liverpool Athenæum.
,, Chemists' Association.
,, Free Public Library.
,, Geological Association.
,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
,, Polytechnic Society.
L'Universite Royal de Norvège, Christiana.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Museum of Practical Geology.
Orleans County Society of Natural Science, Vermont, U.S.
Owens College, Manchester.
Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
Smithsonian Institution, Washington, U.S.
Société Geologique de Belgique, Liege.
Société Geologique du Nord, Lille.
University Library, Cambridge.
Warwickshire Natural History and Archæological Society, Warwick.
Watford Natural History Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-SECOND.

OCTOBER 12TH, 1880.

THE PRESIDENT, WILLIAM SEMMONS, in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been audited by Mr. ISAAC ROBERTS and Mr. HENRY BEASLEY.

The Anniversary Address was read by the PRESIDENT.

NOVEMBER 9th, 1880.

THE VICE-PRESIDENT, ISAAC ROBERTS, F.G.S., in the Chair.

ARTHUR TIMMINS, C.E., was elected an Ordinary Member.

The following communications were read:—

ON SPLIT AND OTHER BOULDERS.

By CHARLES RICKETTS, M.D., F.G.S.

THE CARBONIFEROUS LIMESTONE OF GOWER COMPARED WITH THAT OF NORTH WALES.

By G. H. MORTON, F.G.S.

DECEMBER 14th, 1880.

THE PRESIDENT, DR. J. CAMPBELL BROWN, F.C.S., in the Chair.

The following communication was read:—

NOTES ON THE WORKED FLINTS OF THE RAISED BEACHES OF THE N.E. COAST OF IRELAND.

By FRANCIS ARCHER, B.A.

JANUARY 11th, 1881.

T. MELLARD READE, C.E., F.G.S., in the Chair.

MRS. ALFRED MORGAN, MRS. ISAAC ROBERTS, and MISS MORTON, were elected Associates.

The following communication was read:—

THE LOWER BOULDER-CLAY IN THE COUNTRY AROUND LIVERPOOL.

By G. H. MORTON, F.G.S.

FEBRUARY 8th, 1881.

THE VICE-PRESIDENT, ISAAC ROBERTS, F.G.S., in the Chair.

The following communication was read:—

ON THE SOUTHERN DRIFT OF THE SOUTH OF ENGLAND AND WALES.

By T. MELLARD READE, C.E., F.G.S.

MARCH 8th, 1881.

THE VICE-PRESIDENT, ISAAC ROBERTS, F.G.S., in the Chair.

The following communications were read :—

NOTES ON THE STRATA AND WATER-LEVEL AT MAGHULL.

By ISAAC ROBERTS, F.G.S.

LIST OF PAPERS AND WORKS ON THE GEOLOGY OF THE COUNTRY AROUND LIVERPOOL, PUBLISHED DURING THE LAST 10 YEARS.

By G. H. MORTON, F.G.S.

A MASS OF SAND, CONTAINING VEGETABLE MOULD, EMBEDDED IN THE BOULDER-CLAY.

By CHARLES RICKETTS, M.D., F.G.S.

PRESIDENT'S ADDRESS.

By William Semmons.

During the past year the "Liverpool Geological Society" has attained its majority, and its members must feel that any success it has attained has been largely due to the indefatigable labours of its Secretary.

Since last I addressed you from this chair, the noble liberality of the citizens of Liverpool has rendered the long wished for College of Science an object of near approach. I hope we may see the Chair of Geology therein associated with the subject of Mineralogy, as in the new Science College of Sir Josiah Mason, so that practical results may follow from the teaching of this branch of Science.

In that same period, also, the magnificent collection of Rocks and Minerals—so imperfectly displayed at the British Museum—has been removed to its new home at South Kensington. When the 30,000 specimens of Rocks it contains, illustrating some of the most brilliant and learned of Geological papers—those of Judd, Von Rath, &c.—are fully displayed, the English student of Petrography will have such an opportunity of investigating the structure of rocks as was never before presented to him. Some means will, I hope, be afforded for examining the vast series of microscopic sections embraced in this truly National collection.

All readers of the Principles of Geology must have noticed with what rare insight into the workings of Nature, Lyell describes the difficulties which attend the preservation of the remains of Birds, after death, at the present day.

How truly in this respect can we read the Past by the Present! How rarely do we meet with representatives of the winged tribe in the rocks!

Compared with the adjoining class—Reptilia—how vast is the contrast in the proportion of extinct with living forms!

Of late a vast number of Avian remains have been found in those remarkable deposits of the Rocky Mountains, which, according to Huxley, furnish us with remains of animals that give the pedigree of the horse.

Upwards of 100 individuals of the Bird class are represented by fragments in the Yale College collection from this district, and the vast gap which formerly separated the Avian from the Reptilian class seems to be bridged over considerably by the result of these discoveries.

Birds with teeth, Hesperornis and Ichthyornis—the latter with bi-concave vertebræ—are here met with, as well as Pteranodonta and Sauranodonta, which represent the toothless winged and fish-like Reptiles respectively.

Wonders crowd upon us, and with such as these we hardly need the Archæopteryx to convince us that, hidden in the recesses of the rocks, Nature has stored up "forms of wondrous shape," which show that in the Animal Kingdom there are no ugly gaps or unsightly chasms, but that—

"All are parts of one stupendous whole."

The light which has been thrown on the structure of the Archæopteryx through the further discoveries of this

group at Solenhofen is most important. After the American Cretaceous birds were found to be armed with teeth, it was surmised that this curious animal was also furnished with them, and this surmise has proved to be correct. Prof. Marsh has had such experience with the teeth of birds, that he at once identified those found in the Solenhofen limestone as belonging to this class. But who, only a short time since, would have ventured to suggest that a bird was armed with teeth?

Such, however, are the marked differences in structure between Archæopteryx, Hesperornis and Ichthyornis, that we must look a long way back if we wish to find their common ancestor. The Deinosaurians seem to be the group required, and it is now pretty generally recognised that the most natural way of classifying Birds is by comparing the greater or less divergence of their skeletons from those of Reptiles.

The first appearance of Reptiles must be moved backward in the Geological Record, and though Judd has shown the Elgin (Reptilian) sandstones are undoubtedly of Triassic age, we can hardly doubt that Amphibia, if not Reptilia, lived in Old Red Sandstone times, and walked on the banks of Lakes Orcadie and Caledonia.

In the past twelve months the "Origin of Species" has also attained its majority, and the coming of age has been celebrated by Prof. Huxley in one of those brilliant essays which mark at once the profound thinker and the fearless investigator.

None can dispute the vast importance of the Biological portion of Geology; and we have merely to look back on the state of Biology when the "Origin of Species" appeared, to see how much it owes to the illustrious author of this work. To me it seems the key which

unravels most of the problems which beset us in examining the fossil contents of the rocks and their relation to living forms. The persistency of some animals, and the great variability of others, are accounted for in a manner which commends itself by its clearness and simplicity. Many difficulties, however, prevent the complete acceptance of Darwin's hypothesis, and by none have these been more clearly pointed out than by Prof. St. George Mivart.

I consider the task of completing all the intermediate forms necessary to show a change from one species to another—supposing the theory to be true—to be a hopeless one. But why should we expect intermediate forms at all? This very expectation is silent testimony to the truth of Darwinism. Do such forms as Ichthyornis and the Reptiles in South Africa, described by Owen, mean nothing? Are synthetic forms mere monstrosities? Judge Grove once asked, "Did the first elephant drop from the clouds?" With our present knowledge of the Miocene and Pliocene proboscidians, we may safely infer, that if the first elephant had this celestial origin, he had animals closely related to himself preceding him in this sublunary planet.

The homage paid by Lyell—perhaps the greatest philosophical Geologist—to Darwin, may be taken as evidence of the value of the Darwinian theory to the Uniformitarian school.

To Darwin are we also indebted for that beautiful theory on the mode of formation of Coral reefs and Atolls, which commanded till just lately almost universal acceptance. This attempt to connect the Sciences of Geology and Biology, through the influence of elevation and depression on Coral life, is now opposed by Mr. Murray, of the "Challenger," who considers that

"there are other agencies at work in the tropical oceanic regions by which submarine elevations can be built up, . . . without calling in the aid of great and general subsidences." Prof. Semper also experienced difficulties in the application of Darwin's theory to the formation of the Pelew group of islands.

These "tombstones of Continents" therefore do not mark the site of Continents, says this school.

Are the main Geological deductions from the results of the various deep sea soundings and dredgings to be summed up as follows?

The fixity of the present deep sea basins from early Geological times!

The continuity of the Chalk period to our own day!

The insignificance of Ocean currents!

The upsetting of the Darwinian theory of the formation of Coral reefs!

The importance of the questions raised by these new views to the future of Geology is very great, and I hope that the gauntlet so fearlessly thrown down by Mr. T. Mellard Reade, F.G.S., may lead to the thorough discussion of some of them.

The interesting discoveries in the physical geography of the Bay of Biscay, made during the cruise of the "Travailleur," warn us as to dogmatising on too few data. Even now, with the 23 dredgings taken in this corner of the Atlantic, it is calculated that only one ten-thousandth part of the sea bed between Cape Breton and Cape Penas has been examined. An equal scale would give about six square miles for England and Wales, say a strip of about three-quarters of a mile wide across the peninsula of Wirral. Rather a small proportion to dogmatise on! If such be the case in a limited area, which is considered well worked, how much more

cautious should we be in drawing conclusions from the "Challenger's" soundings. How little can we yet know even of the configuration of the sea bottom!

Supposing a traveller in a balloon, three miles above the surface, passed over the British Isles, and took soundings at similar distances to those taken on board the "Challenger," what ideas would he have as to the hills and valleys of this country? Or on the Continent of Europe, with more than two-thirds of its surface occupied by the great Russian plain, with the plains of Lombardy, Hungary and France in addition; would not our imaginary sounder speak of Europe as a country of plains? Nor would the Siberian plain, or the Prairies, Llanoes, and Pampas of America dispel the illusion as regards other continents. Is it, then, surprising that the Ocean bed was at first looked upon as a level plain, and that closer investigation is showing inequalities at first unsuspected on its surface?

But the inequalities of level are made more manifest as the land rises higher and higher above the sea level, for then the subærial denuding agents act with vastly increased energy. On the contrary, when the land subsides, as each elevated portion is brought to the sea level it is acted on by marine denudation and the valleys are being filled with sediment brought down by rivers. All the forces are thus tending during subsidence to reduce the bottom of the sea to one uniform level, or what might in a sounding of three miles be called level. How unlikely, therefore, supposing "Atlantis" existed in Miocene times and has since been submerged, that we should be able to trace any of its physical features except those of the most marked character!

It has always been a matter of pride to me to notice the part which British Geologists have taken in naming

the various Geological epochs or periods, and to find that although this nomenclature was effected in the very infancy of our Science, very few changes have been made either in the old boundary lines or in the names of formations. A rectification of the frontier line between Silurian and Cambrian has yet to be effected; for though Murchison's influence, being all powerful, enabled him to grasp vast tracts of Cambrian land to get a scientific frontier for Siluria, it is now clearly manifest that the patient working, grand old Cambridge Professor was right in endeavouring to retain his hold of much of his territory and the name of Adam Sedgwick will go down to posterity as one of the most correct of reasoners, as well as one of the greatest of investigators, the science of Geology has been benefitted by.

The Cambrian formation will, therefore, doubtless be much extended in future manuals, and already Woodward has mapped out, in his "Geology of England and Wales," as Cambrian, a large tract of land which in Prof. Ramsay's map is coloured Silurian.

The review of the various formations on the Continent of Europe has naturally thrown great light on our English beds, and by no Geologist are the relations of the Continental beds to our English deposits more clearly shown than by our distinguished honorary member, Prof. Judd. To him we owe the admission of Neocomian into our rock systems, and the Speeton clay of Yorkshire has been shown by him to be representative of an important series of English and Continental beds.

Prof. Judd now states that we have the Oligocene period represented in the Hempstead, Bembridge, Headon, and Brockenhurst series of the Hampshire basin. If we adopt this suggestion, we have a series of Marine and Freshwater beds, upwards of 800 feet thick, in which

the marine fauna and terrestrial fauna and flora can be clearly identified as the same, as in those vast deposits on the continent, which are accepted as Oligocene.

In the past few years—mainly through the labours of Dr. Hicks—a vast intercalation of sedimentary strata has been made in the British Isles, between the Cambrian Rocks and those which are generally considered to be of Laurentian age that are developed along the N.W. of Scotland.

It was well remarked by a President of the London Geological Society, some years ago, that the history of individual Geologists is the history of Geology.

Dr. Hicks first showed that in the lowest Cambrian numerous forms of life were met with, and that several classes of the Animal Kingdom were represented in a zone far below the Primordial zone of Barrande. Chas. Fox, some years ago, naively remarked, "A few small shot dethroned the Primordial Kingdom of Barrande." To Dr. Hicks is mainly due the establishment of another zone, which completely demolishes the claims of the Silurian group to all the rocks at the base of our English fossiliferous beds, containing a large number of life forms. Must we name this as the Primordial Zone, or is it not rather the remnant of a vast range of sedimentary strata, in which were entombed the remains of thousands of animals that are as yet quite unknown to us? Is not the Primordial Zone one of Nature's secrets, like the secret of Life which flies before the scalpel's point, which is beyond the magic of the chemist's art, and which melts away into that impenetrable mist that we call Infinity?

Pebidian and Dimetian beds were first announced as claimants for places among the English rock systems, and the striking unconformity between them (which

indicates a lapse of great time) is now partially bridged over by the Arvonian. Other workers, such as Prof. Hughes, Dr. Callaway, and others, have clearly established the existence of these Pre-Cambrian rocks in various parts of England and Wales; so that future manuals will undoubtedly incorporate Dimetian, Arvonian, and Pebidian rocks in their lists of strata. One or other of the group is met with in Pembrokeshire, Carnarvonshire, Anglesey, Shropshire, the Malvern Hills, Charnwood Forest, &c.

But now we are told by Dr. Hicks that in Scotland too these beds are represented; and, should his recently published speculations on the Pre-Cambrian rocks of Ross-shire prove to be correct, we shall have to alter our readings of the Geological history of this part of our Island, for a new series of rocks will have been brought to view in this locality. The unfossiliferous nature of the beds, and the metamorphism they have undergone, being everywhere completely crystalline, prevent the adoption of the usual methods of determining the age of these beds; but the close connection of their lines of strike with those of beds of similar age in Wales and England furnishes *primâ facie* evidence of their being of the same age. Again, the mineral character of these beds is appealed to by Dr. Hicks in proof of their great age; "minerals being, indeed, to the Petrologist what fossils are to the Palæontologist." Fortunately, Dr. Hicks has called into requisition the invaluable knowledge of Mr. Thomas Davies, F.G.S., in his petrological researches, and consequently no doubt can now exist as to the determination of the minerals.

Dr. Hicks's conclusions are that a floor of Pre-Cambrian rocks can be traced along certain lines from

the West Coast of Scotland to the central mountains of Ross-shire; that the physical and mineral characters associate them with the Dimetian rocks of Wales; but their thickness is here greater than in any part of Wales, and that the main anticlinal axis of the old rocks in the neighbourhood probably occurs in the line of Loch Maree. He thinks it possible that the Lewisian beds are here exposed. Some of Dr. Hicks's conclusions are, however, denied by Prof. Bonny, whose acute and subtle intellect, combined with vast experience in the field and in the study, entitles his views to the utmost possible respect.

Speaking on the subject of the mineral constituents of rocks, how instructive will it be if we find that the suggestion prove correct that the Wolf Rock, off the coast of Cornwall, should prove to be connected with the rocks that were crushed and metamorphosed during the Oligocene period, and with the volcanic outbursts of this age of Fire. Yet the occurrence of Nepheline in the Phonolite of this terrible Wolf, which has gnawed up many a noble ship in its hungry jaws, lends strong support to the idea.

Whilst so few additions have been made to our formations, we find also that all the old names are still retained in our nomenclature. The Devonian system has certainly had its position assailed with great persistency, and had it to rely solely for its claim to existence on the locality from which it derives its name it would have had great difficulty in sustaining it, despite Etheridge's efforts. Germany, Russia, America and even the Arctic regions, however, seem to display between the Silurian and Carboniferous formations a series of beds containing such a distinct fauna that the term Devonian must be retained, if we wish to mark the

series of biological changes that occur in the Evolution of Geology.

The relation of these Marine Devonian beds with those called Old Red Sandstone has been worked out with more or less unsatisfactory results by various workers. Professor Hull, whose experience as a Geological surveyor entitles his remarks to great weight, has lately attempted to reconcile the difficulties of the situation which had been noticed by other observers, and arrives at the conclusion that the Lower Old Red Sandstone of Scotland is the lacustrine representative of the Uppermost Silurian beds of the English and Welsh borders and of the Glengariff beds (ominous name) in Ireland, and forms the connecting link between the Silurian and Devonian formations. The Upper Old Red Sandstone of Scotland is correlated with the Old Red Sandstone and conglomerate (including the Kiltorcan beds) of the South of Ireland and the Upper Devonian Sandstone of Pickwell Down. The hiatus between the Upper and Lower Old Red Sandstone of Scotland and between the Old Red Sandstone and Glengariff grits in Ireland is filled up in Devonshire by the Middle and Lower Devonian formations. The Foreland grits are supposed in this case to be the equivalent of the Upper Ludlow and Glengariff beds.

The simplicity of the arrangement is charming, and Prof. Hull dilates with ecstasy on the changes in the position of land and water which gave rise to these conditions. There was a general elevation of all the Northern and Western portion of the British Isles, while in the South there was continuous depression during the Lower Old Red Sandstone period. With the Upper Devonian (Hull's Old Red Sandstone proper) the submersion of the western and northern portions of the

British Isles began. By a further general subsidence at the commencement of the Carboniferous period, the sea waters flowed in, establishing themselves over all the lower regions. With all these changes dovetailing themselves into one another in proper order, it looks like ruthless vandalism for even the eager patriotism of Irish Geologists to attempt to deny the sequence given.

Last year, when speaking of the connection of volcanic rocks with Granites, I asked what had become of the ancient volcanoes of Leinster and Cornwall. This question has been to a slight degree answered by Frank Rutley, F.G.S., who has restored an old volcano at Brent Tor, and traces from its central flue the beds of volcanic ash, &c. We have here lavas, tuffs, and ashes interstratified with sediments which are probably of Devonian age. If the schistose lavas of Saltash and Tavistock are of the same age, we might have here, as suggested by Rutley, the remains of a very large and once continuous flow.

J. A. Phillips, in a series of interesting papers on the "Greenstones" of Cornwall, shows that these schistose lavas are not unfrequently met with in Cornwall. They are generally Gabbros or Dolerites, and are often associated with flows of vesicular lava. Phillips also shows they are interbedded with the slates; but Rutley is, I believe, the first to prove the relations between the flow and the volcano, though perhaps the merit of suggesting the idea, as regards Brent Tor, belongs to that distinguished man, of whom all English Geologists (and particularly Petrologists) are so proud—Sir Henry de la Beche—who, in the days when microscopical sections were unknown, seemed to have an intuitive perception as to the difference between lavas and the metamorphic

schists. I need not add that this is by no means an easy matter in our days of advanced Petrological knowledge.

The workers in Microscopical Petrography have by no means been idle in the past twelve months, and the insight gained into the changes in the internal structure of rocks is very great indeed. One point, however, should never be forgotten when a description of the microscopic structure of a rock is given. The section is necessarily of a small size, and without a considerable number of them are taken and the rock is of a very uniform character throughout, very incorrect conclusions as to the mass may be formed.

I have particularly been struck with this idea whilst noticing the Granite blocks which form the pavement of London Bridge. The blocks are generally about 9 by 3 feet, and have been polished to a smooth surface by the feet of the countless thousands who have passed over them. Here we have fine-grained Granites which seem a mass of imperfectly formed crystals of Quartz and Felspar, Granites of ordinary character, and others which have large porphyritic crystals of Felspar three or four inches in length, and seemingly—if we may judge from their section—perfectly formed. The particular point to which I wish to call attention is that in some of the blocks we have a portion quite porphyritic in character, whilst the other portion is quite fine grained. Again, we sometimes meet with nests of crystals, say in a rude circular piece of about one foot in diameter, the remainder of the stone not having this character. Perhaps in another case we meet with two, or even only one crystal of Felspar, standing out, of a white colour, and measuring two inches long, in a mass of finely-grained dark grey stone.

It is quite evident that where such great changes of structure are met with in such a small space we should find where Granitic rocks have been examined microscopially a vast divergence in the slides of different observers. The same remarks will apply more or less to sections of other rocks; but perhaps more particularly to those of the Igneous group.

Daubrée, some years ago, called attention to the analogy of the Lherzolite rock of the Pyrenees to the rocks composing some of those other worlds that have fallen on the surface of this planet. Von Lasaulx has shown how closely allied to Lherzolite are the Olivine bombs which are met with in some basalts. We are thus naturally led to the consideration of the large masses of what was called Meteoric Iron, which, weighing from 1 kilo to 21,000 kilos, have been found on the sea shore at Ovifak, in the Isle of Disco. These masses are found amongst rounded blocks of Granite and Gneiss at the foot of a basaltic cliff. In a dyke of Basalt, about 20 yards from the largest block, were found several lenticular masses of Nickeliferous Iron, which resembled Meteoric Iron in composition, and in the resistance which they offered to the action of the atmosphere. The first examination of these immense masses naturally led observers to consider them as of extra terrestrial origin, and some were brought back to Europe and exhibited in various museums as Meteorites. It was, however, early noticed that the Island of Disco consisted of beds of the Miocene formation resting on beds of Gneiss, and that these Miocene beds contained many layers of Lignite and Fossil plants, which are traversed by beds and dykes of Basalt. Further, it was noted that the carbonaceous matter in the immediate neighbourhood of the Basalt was converted into

Graphite, and that the Basalt contained metallic iron in large elliptical masses, in small balls and fine particles, and sometimes in the form of small veins. Still the occurrence of Native Iron as a constituent of terrestrial rocks was considered so rare that, notwithstanding twenty masses were met with in a space of 100 square yards, they were looked on as portions of other worlds, and Tschermak, in accounting for their presence in the dolerites of the locality, supposed they fell into the Basalt whilst it was still in a state of fusion. He classed them as Meteorites, consisting of Eukrite (Anorthite and Augite), Metallic Iron, and Troilite.

Daubrée, by fusing Basalt and Lherzolite in a crucible lined with charcoal, obtained metallic Iron, analagous to that of Ovifak in appearance and chemical composition. The combined labours of geologists and chemists in the past year or so have, therefore, caused us to no longer recognise these large blocks as extra terrestrial rocks, but our interest in them is none the less, as it seems probable they represent portions of the heavy materials comprising the crust of the Earth which have been floated up from below.

Considerable interest, consequently, attaches to the Igneous rocks which belong to the Olivine Enstatite group; and this is not lessened by finding that a rock of similar composition forms the matrix of the diamond in the South African fields. Enstatite, a mineral with a brilliant lustre, seemed to be one of those which, though found in small crystals embedded in the rock, was hardly known in an isolated position. In the past few months enormous crystals about 12 inches long have been brought over here from Balme, in Norway, so that one can now point to a substantial piece in our museum at Jermyn Street, as representative of the

mineral, instead of picking out little lustrous fragments scattered throughout a matrix. We notice the outer portions of these large Enstatite crystals decompose into Steatite, which is confirmatory of their close connection with the Serpentine rocks.

The close analogy between the Terrestrial and extra Terrestrial rocks can scarcely be more clearly shown than in the fact that a group of rocks which was for several years supposed to belong to the one, is now found to belong to the other; it now does not surprise us to learn that among the lavas of Ireland are found rocks precisely similar to that of the Meteorite, which fell on July 14th, 1845, in the Commune du Teilleul Manche, which belong to Rose's group of Eukrites.

The interest naturally associated with the connection of the Lherzolite with extra Terrestrial rocks has probably been the means of our at last being able to trace the origin of that curious class of rocks called Serpentine, of which such magnificent cliff sections are to be met with at the Lizard Point in Cornwall. Serpentine has almost always (since any attempt to classify rocks was made) been regarded as a metamorphic rock, and Cotta says it has been formed from Gabbro, Granite, Gneiss, or an Eklogite rock in the Gneiss, and from Chlorite Schist. Jukes considered many Serpentines are metamorphosed magnesian limestones. To the indefatigable labours of Prof. Bonney is due the solving of the problem in most of the Serpentine rocks exposed in Western Europe. Bonney shows that many of the Serpentine masses are intrusive, and that in the case of this rock at the Lizard, Ayrshire, Portsoy, N. Wales, the Island of Elba, and the Ligurian Appenines, it is an altered Olivine rock of Igneous origin.

Microscopical examination shows in many cases every gradation from an unaltered piece of Olivine to one that is completely changed to Serpentine. As bearing on this subject, one must notice those fine pseudomorphic crystals of Serpentine after Olivine in the British Museum, where every trace of the original mineral is obliterated. If the Olivine crystal has thus been changed into Serpentine, and the imperfectly formed crystals in the rock are more or less changed into the same substance, nothing seems clearer than that the rock masses have been changed from one class of rock to the other. Serpentine being thus transferred to the Igneous group of rocks, its intrusive character follows as a natural consequence.

It is probable some other term will be adopted for those rocks which have somewhat the appearance of Serpentine, but not its composition, and the term Serpentine retained only for those rocks in which the ground mass consists almost entirely of Hydrous Silicate of Magnesia, with some Oxide of Iron.

An important series of microscopical observations have been made by C. Le Neve Foster and J. H. Collins on the vein-stones of the Tin lodes of Cornwall and the rocks in which they are found. The pseudomorphic crystals of Cassiterite (oxide of Tin) after Orthoclase Felspar are well known to Mineralogists. Collins says it also occurs pseudomorphic after Quartz, and this is confirmed by Foster; and I can now, after seeing the collection of the late W. M. Tweedy, unhesitatingly state this to be the case. The microscope shows that the Tin-stones merge into the Tin capels, the capels being merely a Tin-stone which does not contain enough Tin to pay for working. These capels are sometimes Granitic and sometimes schistose in their character, and

represent modifications of the Granites and Clay-slates of the district.

The Granitic capels are shown on very strong evidence to be Granite rocks altered *en masse*, the Felspar mostly changed to Quartz, and the Mica to Schist and Chlorite. In almost every case Tourmaline is present. The schistose capels also contain Tourmaline, in some cases in large quantities, and Collins says the final products of the cycle of changes in these rocks are the acicular crystals of Tourmaline, which are often met with. Foster, writing on the Great Flat Lode south of Redruth and Camborne, shows that this lode at the junction of the Clay-slate (Killas) and Granite, has the one rock on one side, and the other on the other side. Further, he adds, there is no line of demarcation between the Granite and the lode, the passage being quite gradual; nor is there any line of demarcation between the killas and the capel. These facts, says Foster, point to the idea that the lode and capel are merely altered rocks, and that the fissure now occupied by the leader (the richest part of the lode) served to bring up vapours or solutions capable of entirely changing the rocks on both sides of it. A hint is given that at one place the position of the pipe, up which these vapours or solutions came, has been discovered. At South Wendron Mine an oval pipe, varying from 20 to 60 feet in length, and about 10 feet wide, is met with, composed of Tinstone, Quartz, and Tourmaline. This passes on all sides into Granite, and the percentage of Tin-stone decreases as we recede from the main leader.

Dr. Foster, who from his position as Inspector of Metallic Mines, had exceptional opportunities for making observations, considered that last year it was probable one half the Tin ore raised in Cornwall was obtained from

masses of Stanniferous Granite. The occurrence of Tourmaline is *primâ facie* evidence of alteration. This idea was held by Sir H. de la Beche, and M. Pisani. Bonney shows that in Luxullianite the Tourmaline has been derived from the Felspar of Granite. The composition of Tourmaline, with its analogy to the heated emanations from volcanic districts, lends support to the connection with a highly heated source.

In connection with this subject of Tin deposits, I would like to place on record in the Proceedings of this Society my conviction that deposits of Gold will be met with in the deep workings of the Cornish Tin mines. I cannot believe that the association of Native Gold and Cassiterite in alluvial deposits is a mere accident.

With what interest must we all follow Sorby in his examinations of limestone rocks, when we see how beautifully Nature reveals herself to us in the varied effects on light when passed through crystals belonging to the different systems of crystallographers. As is well known to you all, Carbonate of Lime crystallizes in two forms: in the forms belonging to the Rhombohedral system it is known as the Mineral Calcite, and in those belonging to the Prismatic system as Arragonite. The Polarising of Light, by means of apparatus easily attached to an ordinary microscope, enables us without difficulty to determine which of the two minerals we are dealing with. Mr. Sorby, following in the footsteps of other observers, shows how in the various Mollusca and other invertebrate animals, sometimes one and sometimes the other of these minerals is met with. As Calcite is a very stable form and Arragonite a very unstable form of the compound, we should naturally assume that those organisms which are composed of Calcite would be the more frequently met with. Not only is this the case, but in those

instances where an organism is partly composed of each mineral we find the Arragonite portion has been dissolved out, and the Calcite portion remains behind. The Echinodermata, being of Calcite, seem to be wonderfully preserved, even to the minutest spines of Sea Urchins. One must pause to wonder at the miraculous play of the animal forces in the formation of these spines, if, as Sorby (confirming other observers) says, they are each composed of a single crystal of Calcite, having its principal axis in the direction of the greatest length of the spine. In this case the animal seems merely to be endowed with the power of modifying the crystallising forces to a slight extent. The hand of the moulder is only competent to modify even the external shape to a small degree. Silently but irresistibly does molecule form upon molecule, according to the unerring law which builds up the flowers of the Mineral Kingdom. In other organisms we seem to have proof that the crystallising forces have but little power against the life energies.

It is in such cases as these we see the meeting of the Organic and Inorganic forces of Nature, and the wide divergences of opinion in most competent observers, who have closely examined with the microscope, afford proof, if any were needed, that we are as yet unable to form a judgment as to their relative powers.

For a complete account of Mr. Sorby's researches, I would refer to his Presidential Address to the London Geological Society last year. They point to the great part played by Encrinites in building up the masses of finely grained Palæozoic rocks, and to the influence of chemical deposits in our Oolitic rocks, whilst in our Tertiary beds Freshwater Arragonite Mollusca form no inconsiderable part.

The Microscope does not, however, with all the wonderful insight it gives us into minute structure, yet tell us how Dolomite has been formed, and this rock remains, as in the past, one whose origin remains obscure. We should like to have known if any confirmation of Sterry Hunt's views could be obtained by this new method of research. The physical theories of Prof. Ramsay certainly accord with Sterry Hunt's chemical theories hereon, and it is at least satisfactory to know that there is no evidence to the contrary from microscopic examination.

My distinguished predecessor in the Geological Chair, at the Liverpool School of Science, the late Dr. Birkenhead, F.G.S., delivered in 1862 a valuable address on Micro-Geology, before the Historic Society of Lancashire and Cheshire, which contains all that was known up to that date. Sorby's researches into the characters of the igneous rocks were then only just made public, and the whole of the microscopic work, we may say, consisted in the determination of the minute organisms composing some of our sedimentary rocks, and the constituents in a less degree of others. "I have no desire," says Dr. Birkenhead, "to exalt Microscopic Geology to the dignity of a separate science." In these days it is rather difficult to define a separate science; but I think I have shown by the various researches I have brought before you in this address, and my address from this chair last year, that Micro-Geology holds quite as important a position as some so-called separate sciences.

In Geology, however, we have to deal not only with the microscopic and molecular condition of rocks, with action and reaction on a small scale; we have to chronicle the greatest efforts of Nature; we have to deal with a grand philosophy.

The landslip at Naini Tal tells us that the days of Cataclysmal Geology are not yet over. Accumulated energy still occasionally asserts its existence now, as in the past; and the same forces that did Geological work in Cambrian times are yet active. Prof. Ramsay, indeed, seems to think that the average intensity of Geological agents over the whole globe is about the same now as in the remotest past we can trace back to in the Geological evolution of our planet. Frost and Snow, Rain and Rivers, Volcano and Earthquake, Landslip and Avalanche—yea, even the Lightning flash—all have left their mark behind. Yet how differently do the Cataclysmal and Uniformitarian aspects of Geology strike our senses! Take, for example, the single instance calculated by one of our greatest living Geologists—that the great well at Bath has since the Roman occupation carried silently away in solution from the Earth's interior about the same quantity of solid matter as was erupted in a few days when Monte Nuovo was formed. Who but a Geologist could have believed this possible? Prof. Huxley, in his Presidential Address to the Geological Society, showed that the Uniformity of Nature was not incompatible with Cataclysms.

We must remember that it is the silent uplifting of the simple molecule of vapour which enables the deluges of India to be formed, and the mighty rhythm of the Niagara Falls is but another manifestation of the same force. So, likewise, the waves on the sea shore, sweeping away with a scythe-like action the frowning cliffs, and the energetic island streams, carving out the dale and valley, are but illustrations of the power of that gentle warmth that causes the grateful flower to breathe out its fragrance, and the noble tree to bear its graceful foliage. Thus we see that the pent up, or rather stored

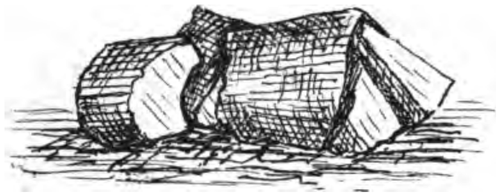


FIG. 1. AFTER MR. J. SMITH, OF JORDAN HILL.

FIG. 2. CARBONIFEROUS LIMESTONE.—YEALAND.

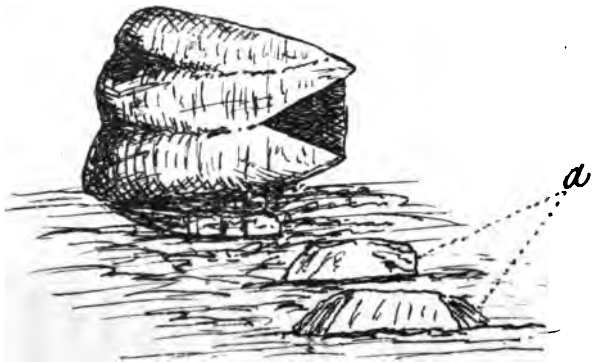


FIG. 4. SILURIAN GRIT.—NEAR SETTLE.

FIG. 3. SILURIAN GRIT.—NORBER SCAR.

up, Uniformitarian agents give rise to the most striking of Cataclysms. In the Biological portion of Geology we find all the changes are of a gradual nature. Mollusc, Amphibian, Reptile, Bird, and Mammal, follow each other in succession, and the tendency of discoveries seems, in my opinion, to point to modification and divergence from synthetic forms.

From what have these animals sprung? Nay, further, we involuntarily ask from what has our earth been derived, and to what is it tending. A darkness, as of space, is around us, and Geology is no longer our guide in seeking our "whence and whither."

ON SPLIT AND OTHER BOULDERS.

By Charles Ricketts, M.D., F.G.S.

In North Lancashire and the neighbouring border of Yorkshire, large boulders of such hard rock as Carboniferous Limestone and Silurian Grit are frequently met with; of these some are split entirely through, having the fractured portions remaining in exact apposition; or the different fragments are separated by a short space, but lie in such a position that they can be readily and certainly determined as having originally formed one block.

In the Reports of the British Association on the erratic blocks of England and Wales, very slight reference is made to any which have been split, two examples only being given.* The late Professor David Page, in "Chips and Chapters for Geologists," has alluded to

* Reports for 1878–9.

† Quart, Journ. Geol. Soc., vol xviii., p. 162.

such boulders formed of Granite, Porphyry, Greenstone, Limestone, and Sandstone, in blocks of all sizes, from one to one hundred tons. He considered the explanation given either by Mr. Smith, of Jordanhill (see Fig. 1), that they had fallen from a height at the termination of glaciers,† or of Mr. McLaren, that they had fallen from high and wasting cliffs, may in some instances be sufficient to cause the fracture; but was himself inclined to refer their condition to the impact of an ice-mass, in which as a glacier or ice-berg the block was imbedded, coming forcibly in contact with a submarine ledge. Each of these hypotheses supposes a concussion so sudden and severe as to fracture the rock. Under such circumstances some signs of the point of impact might be expected to be discovered, and it is most improbable that the fragments would remain as they do in almost exact contact; or, if they had been imbedded in glaciers or ice-bergs, they would be removed to the distance of a few inches only, being such as would probably occur by falling from each other at the time of their complete separation.

Resting on the Carboniferous Limestone of Warton Crag, near Carnforth, Lancashire, are many isolated blocks of limestone, probably derived from the immediate neighbourhood; those designated the "Three Breeders" being the largest. Many erratics of Silurian rocks are scattered over the fell, and occur in moraine accumulations, and blocks of Shap Granite and other Porphyries have been disclosed in a moraine at Yealand. So that the boulders on Warton Crag and at Yealand may be referred to any locality south of the Wast Dale Head range, where such rocks occur.

Many of the limestone boulders are deeply fissured, as if the act of splitting is still in progress, the indenta-

tions being so weathered out that mosses, ferns, grasses, and even small shrubs grow in the interstices. Several have been split through into two or many pieces, the fragments remaining near together, separated to such an extent only, as the impetus from the fall upon the act of separation might, and probably did occasion; they can certainly be determined as originally belonging to the same block. One situated above the village of Yealand, a few score of yards to the north of the summer-house, which has been fractured into many pieces, is considered by the residents to have been struck by lightning. (Fig 2.)

Over a surface of country extending from Morecambe Bay to the eastern flanks of Ribblesdale are an abundance of blocks of Silurian Grit, locally known as "Calliard," of all sizes from that of a pebble to large boulders twelve feet or more across, but especially observed lying on the lower beds of Carboniferous Limestone, and on the Silurian strata on which these rest. The valleys in this district extend in a direction from north to south, and in each, Silurian strata are exposed somewhere to the northward of where the blocks are lying. They are in greatest abundance on the flanks of the valleys, a short distance southward of the locality whence the blocks have been derived, being often perched on the limestone at a higher elevation than the places where similar rocks *in situ* are overlaid by horizontal beds of Carboniferous Limestone.

It may be remarked that the beds of the different brooks or "becks," appear to have been excavated to about their present depth, prior to the formation of glaciers in their respective valleys; for the remains of cañon-like gorges occasionally occur as in the limestone of Clapham Dale, above the entrance to Ingleborough

Cave, where, in all probability as the effects of glaciation, a smooth surface slopes down until it joins the perpendicular sides of the gorge; being an example on a smaller scale of phenomena seen along the course of the Wye, between Buxton and Bakewell. At the now unused Ingleton slate quarries a somewhat similar cañon-like gorge has been cut through hard Lower Silurian grits and slates. From these and other examples it may be inferred that in pre-glacial times these watercourses existed as cañons with banks nearly perpendicular, extending through the whole thickness of the Carboniferous Limestone; being, on a miniature scale, no inapt representation of those of the Colorado.

In some places the "Calliard" blocks are isolated, in others are in close approximation, or even piled upon each other. They must formerly have existed in even greater numbers, having been greatly used in the making of fences, sometimes forming the entire structure of the wall; or when Millstone Grit or Limestone preponderate, they are utilised for "throughs," (blocks passing *through* the whole thickness of a wall to bind it together). They exist in great abundance on the flanks of the valleys, and were nowhere observed in such abundance as on those of Crummack Dale and on the Carboniferous Limestone of Norber Scar (a spur of the Ingleborough mountain at the entrance to the dale), and on the Silurian rocks which form its base, whence they spread westward as far as the water-parting between Austwick Beck (the stream issuing from Crummack Dale) and Clapham Beck.

Numerous isolated blocks of Silurian Grit are scattered over the Carboniferous Limestone above Settle, and many were uncovered in acquiring access to Victoria

Cave, which is 1,450 feet above the sea level.* As 1,160 feet is the greatest elevation at which Silurian rocks occur *in situ* in Ribblesdale,† these boulders must have been raised, at least, 290 feet from where they were originally derived.

Professor Sedgwick, in 1851,‡ and Professor Phillips, in 1853,§ recorded the occurrence of these blocks at Norber, and on Moughton (the Scar on the opposite side separating Crummackdale from Ribblesdale). Compelled to attribute their presence to glacial action, they both regarded them "as uplifted and floated by ice, and dropped on surfaces which had been swept by currents clear of other loose matter." It may be this idea originated from observation of the carrying power of ice for great distances in the bed of the St. Lawrence. The hypothesis was applied by Sir Henry de la Beche, in 1832, to account for the position of large blocks similarly situated in Alpine countries, but he cautiously declined to consider such explanation as a well-ascertained truth, but merely as an hypothesis, which future and extensive observation may or may not prove correct.‖

As these blocks in many instances rest at an elevation of more than two hundred feet above any locality from which they could by any possibility have been derived, the application of this hypothesis is rendered absolutely untenable; there is likewise not the least evidence that, at the time they were placed in their present position or since, the sea has at any time covered this district.

Amongst these blocks are some which have cracks

---

* Professor W. Boyd Dawkins. † Professor John Phillips.

‡ Quart. Journ. Geol. Soc., Vol. viii., page 53.

§ "Rivers, Mountains, and Sea-Coast of Yorkshire," page 111.

‖ "Geological Manual," by Henry T. de la Beche, F.R.S., page 177.

passing entirely through, splitting them into two or many parts; if such rest with a flat surface on the ground, the fragments remain so nearly in apposition that a few blades of grass only can grow in the crevices. Where not thus supported the fragments are removed to a short distance from each other,—for such a space and to such a position as they would take by falling from each other in the act of separation. (Fig. 3.) A remarkable one occurs as an isolated block at Winskill, two miles north of Settle, at an elevation certainly greater than are the Silurian Grits *in situ* a few miles up the Valley of the Ribble; it rests on Carboniferous Limestone, which, being protected from atmospheric disintegration by this erratic block, forms a pedestal slightly elevating it above the general surface. A large gap has been formed at one end of the stone, and two fragments, just sufficiently large and of such shape as would fill up the vacancy, lie within a few feet, at just such a distance and so placed as if they had fallen from the gap. (Fig. 4*a*.)

The position in which these boulders lie can be attributed to no conditions at present existing in the British Isles; nor can they have been carried there by floating ice as occurs in the River St. Lawrence, but, composed of locally derived rocks, it must have been due to local causes. The only power capable of effecting it appears to be that of glaciers formed by the snow which has fallen on the respective waterslopes of the different valleys. Moraine accumulations containing ice-marked and other pebbles, are found in the lower country in near vicinity to these dales; more generally formed, not in the direct course in which a glacier may be supposed to have flowed, but upon the sides,—that is, they are lateral moraines.

The contour of the ground has had a great effect in determining the position of these boulders. At the foot of the escarpment, between Norber Scar and the entrance to Clapham Dale, the area extending from the limestone to the fault, secondary to the Great Craven fault, is formed of Silurian slates; thus a hollow has been caused between the limestone of the escarpment and that thrown down by the secondary fault. A glacier issuing from the contracted valley would here find room for expansion, and, being thus removed from the main current, would, during successive thaws, deposit there the blocks with which it was loaded. In the form of the ground may also be found an explanation why many of the blocks are perched on the limestone escarpment, &c., at a greater altitude than the strata from which they have been derived. A little within the entrance to Crummack Dale the Coniston Limestone and Upper Silurian Grits dip to the North East, and form ridges, extending diagonally from North-West to South-East, across the valley; the Silurian Grits, on being broken off from their beds, the more readily that they are interstratified with thin beds of slate, locally known as "Calf," * would have had the detached blocks carried up these planes by pressure of the accumulated snow as it progressed down the valley.

On the heights above Settle, blocks of Silurian Grit are lying on Carboniferous Limestone at an elevation greater by about 300 feet than any strata from which

* Similar thin bands of slate, having distinct cleavage planes, even when their thickness is only an eighth of an inch, are common at Arco, and other Flagstone quarries in Ribblesdale, and also occur in the Flagstone quarries near Llangollen, North Wales.

they can possibly have been derived. The Vale of the Ribble, above Horton, is formed in Carboniferous Limestone; from below this the bed of the river and the sides of the valley, to a considerable height, consist of contorted grits, flags, and slates, the denuded edges of which are overlaid by horizontal strata of Carboniferous Limestone; south of Moughton the limestone has been entirely removed and the valley expands until, at Great Staniforth, three miles north of Settle, it again becomes contracted, a gorge being formed by limestone rocks. It may, therefore, be presumed that a glacier formed higher up in Ribblesdale, finding an obstruction in passing through this gorge, would be forced up over the barrier of limestone at the upper entrance, and overflow the escarpments which form its sides, carrying along the materials embedded in it, until it could find a means of emergence in the open country beyond.

There remain for consideration the causes by which some of these boulders have been fractured entirely through their whole mass. It has been shewn that such fracture could not have occurred as the effect of a blow or fall, and there is not the least evidence in any examined by which it can be attributed to such a cause. The blocks must have appeared whole at the time the diminishing glacier left them in the locality where they now lie. The chemical effects of prolonged exposure to the weather have only altered the Silurian Grit to a very short depth from the surface. The hard and compact character of the blocks, and their imperviousness to moisture, have preserved them from the effects of those changes which would have disintegrated most other rocks. I see no explanation but that these fractures have been occasioned by those exposures to atmospheric vicissitudes which cause successive changes in the

expansibility of rocks; the successive expansion and shrinkage by heat and cold; by wetness and dryness; by frost and thaw. The constant repetition of such climatic changes must eventually break up and disintegrate rocks, however hard and indestructible they may be. In some of these boulders there may have been joints in progress at the time the blocks were carried away by the force of the moving glacier; should there have been such, continued exposure would cause these concealed joints to increase, until sooner or later the rock would be fractured entirely through.

THE CARBONIFEROUS LIMESTONE OF GOWER, COMPARED WITH THAT OF NORTH WALES.

By George H. Morton, F.G.S.

The Maps of the Geological Survey, Sheet 37 and 41, and the Horizontal Section, No. 3, Sheet No. 7, represent the Gower district. The country was surveyed in and about 1837 by De la Beche and Logan, some corrections having been since inserted. The date of the section is somewhat later, but the outlines of the formations correspond exactly with the Map. I have not been able to find any description of the Geology of the district around Swansea, or of Gower, except the article in "Science Gossip" for August and September, 1880, by Mr. H. B. Woodward, F.G.S., entitled, "A Sketch of the Geology of Swansea and the Neighbourhood," wherein are described the Cambrian, Silurian, Old Red Sandstone, Carboniferous and other formations shewn on the Survey Maps.

Mr. Woodward informs his readers that the Old Red Sandstone is 5,500 feet thick, of which about 4,000 feet belong to the upper subdivision of red sandstone and quartzose conglomerate. The lower subdivision consists of marls with cornstones. The Lower Carboniferous Shale only presents traces of its occurrence round the base of the Carboniferous Limestone in Gower. The limestone at the Mumbles and at Worms Head varies from 1,200 to 1,500 feet in thickness.

The Millstone Grit does not occur in Gower, but its place seems to be occupied by the Gower Shales, about 1,636 feet 10 inches of various shales, sandstones and limestones along the course of a stream at Bishopston, a few miles from Swansea, show the general character of the formation. Further north at Mynydd Garreg, &c., the Millstone Grit is a thick sandstone formation with a conglomerate at the base.

The Coal-measures are separated into Upper and Lower by the Pennant Grit, a formation peculiar to S. Wales, 3,246 feet thick in the Town Hill, Swansea, the strata being principally sandstone. The only peculiarity deserving of notice in the Pennant Grit is the occurrence of nodules of coal in a bed of matted stems and other vegetable matter described by Logan.

Mr. Woodward describes the Triassic, Liassic, and Post Pliocene, including caverns and recent deposits, and states that Dr. Falconer considered that the Gower caves were filled with the Mammalian remains after the deposition of the Boulder-clay. He is of necessity very brief in his descriptions, that of the Carboniferous Limestone being limited to the following paragraphs:—

"The Carboniferous or Mountain Limestone consists for the most part of grey and bluish-grey limestone and encrinital marble; broken encrinites being more abun-

dant in the lower portion, corals in the upper. It forms the main portion of Gower, from the Mumbles to Worm's Head, where it is from 1,200 to 1,500 feet in thickness. At the latter place it is much disturbed and faulted. Near Oystermouth Castle the upper beds consist of a few feet of dark-coloured carbonaceous limestone, intermingled with siliceous matter, and in places highly fossiliferous. This bed, described by De la Beche, is said to occur here and there along the boundary of Carboniferous Limestone between Swansea and Caermarthen bays.

"The thickness of the limestone is estimated at upwards of 2,000 feet in Caldy Island; while near Llangadock, on the north side of the Coal-basin, it becomes reduced to 510 feet.

"Among the fossils recorded from the district are remains of fishes; mollusca of the genera Chonetes, Spirifera, Productus, Orthis, Retzia; polyzoa of the genus Ceriopoda, the crinoid Actinocrinus, &c.

"Here and there traces of galena have been met with in the limestone, and there are 'Old lead works' between Llangan and Penlline, about four miles south-east of Bridgend." *

The Carboniferous Limestone of Gower is well exposed within a few miles from Swansea. On the east side of Oystermouth Castle there is a quarry, close to the tramway terminus, where the strata consist of thin bedded black limestone, with intervening thin layers of shale of the same colour. The strata are very different to any other beds about the Mumbles, and seem to be the highest in the Carboniferous Limestone, just below the Gower shales. Fifty or sixty feet of strata are exposed, and they are all of the same thin-bedded character, with a considerable dip to the south-east. I am

* "Science Gossip," No. 188, Aug., 1880, p. 172, Vol. 16.

not certain that I saw the identical bed, described by De la Beche, but the highest visible beds contain fossils much the same as described by him; the following I noticed myself, viz.:—*Chonetes Hardrensis*, *Productus semireticulatus*, *P. costatus*, *Spirifera bisulcata*, *Terebratula hastata*, and *Fenestella plebeia*, all common species in the Upper Grey Limestone in North Wales.

A few hundred yards to the south-west of the Castle there is another quarry, where the limestone is of the same dark colour, but the beds are much thicker and form an anticlinal, with a general dip towards, and consequently under, the thinner beds already described.

From Oystermouth to the Mumbles the limestone is well exposed in precipitous cliffs along the coast, to which the beds dip at an angle of 60° or 70°, so that the upper surface often forms the mural exposure. The limestone is very hard and has been much altered and in places converted into dolomite. There are some beds of rubble interstratified with it, but very few fossils occur. The same beds of limestone continue to Mumbles Point, and the two islands beyond, the furthest being Mumbles Head. The strata are exposed over a great portion of the promontory between Oystermouth and the sea, all being of the same dark colour, though they weather and appear white when not broken, and when seen from a distance. The Mumbles limestone lies immediately under the thin-bedded black strata of Oystermouth Castle, and the whole may be considered to be Upper Carboniferous Limestone.

Around Coswell Bay, two miles to the west, the limestone is of a similar dark colour, but very massive in its character, with merely bedding planes giving it a stratified appearance. It seems to have been deposited in a single stratum, several hundred feet thick, for there

is no trace of interstratified shale. Calcite occurs, along some of the bedding planes, crystallised in the same manner as in the joints, which are at a right angle to them. The limestone is usually of an oolitic structure, and there are numerous large specimens of the corals *Lithostrotion irregulare*, and *Syringopora, sp.*, &c. The oolite structure is confined to the lower or middle beds of the limestone; for I carefully examined the limestone about the Mumbles without finding any trace of it, though it is of general occurrence in the strata around Coswell Bay, and indicates a lower horizon. Although the strata are very much faulted, and present synclinals and anticlinals so that their position in relation to the limestone at the Mumbles cannot be readily ascertained, it seems that they must belong to the middle, or lower portion of the Carboniferous Limestone. There is, however, no actual base to be seen in the locality, and it is most probable that the Limestone Shale and the Old Red Sandstone are several hundred feet below the surface. At Oxwich Point the limestone is said to be of a light colour, and compact like marble. It is on about the same horizon as the Coswell Bay beds.

The following is a list of Fossils from the Carboniferous Limestone; it appeared in "Science Gossip" for November, 1880, Vol. xvi., p. 260.

They were collected in the vicinity of Swansea during the meeting of the British Association, with the exception of a few species in the Swansea Museum and the collection of Mr. N. Terrell:—

1. *Euomphalus Dionysii.*
2. *Terebratula hastata.*
3. *Spirifera lineata.*
4. ,, *glabra.*

5. *Spirifera bisulcata.*
6. ,, *attenuata.*
7. *Rhynchonella accuminata.*
8. ,, *pleurodon.*
9. *Productus cora.*
10. ,, *giganteus.*
11. ,, *longispinus.*
12. ,, *Martini.*
13. ,, *punctatus.*
14. ,, *semireticulatus Var. costatus.*
15. *Orthis resupinata.*
16. *Chonetes Hardrensis.*
17. *Athyris ambigua.*
18. *Fenestella plebeia.*
19. *Phillipsia truncatula.*
20. *Syringopora reticulata*
21. *Lithostrotion irregulare.*
22. *Cyathophyllum Stutchburyi.*
23. *Clisiophyllum turbinatum.*

All these species occur in the Upper Grey Limestone of North Wales, and most of them have been found near Llangollen. Although *Productus giganteus* is very common in North Wales, it seems rare, or by no means common, in Gower.

Although several times over the base of the limestone and the Lower Limestone Shale I saw no exposures of either, and consequently can only judge of their thickness from the general aspect of the country, which I had a fair opportunity of doing—map and section in hand. Cefn-y-bryn, the backbone of Gower, is a long stone-covered ridge of Old Red Sandstone, composed of a red conglomerate, with white quartz pebbles, which are usually an inch or two in diameter. This rock forms the numerous stones lying over the heathy surface; it is exposed in several

places, and is used for building walls and such like rough purposes. It forms an anticlinal along the crest of the ridge, so that the thickness actually exposed may not be very great. The Geological Survey Section shows the Old Red Sandstone to be altogether of considerable thickness—the overlying Lower Limestone Shales 100 feet; the Carboniferous Limestone 1,400 feet; and the Gower Shales 1,600 feet.

The united thickness of the Carboniferous Limestone, with the underlying shale, being about 1,500 feet, is about the same as North Wales, in the neighbourhood of Llangollen and Mold. The formation is somewhat similar both in North and South Wales,—in both black limestone forms the upper subdivision with interstratified shale, and a very similar group of fossils. The lower beds of the Lower Brown Limestone at Llangollen bear a strong resemblance to the Lower Limestone Shale; the chief peculiarity of the Carboniferous Limestone in Gower being its massive character, and absence of shale; and the occurrence of the oolitic structure in the middle and lower portion of the limestone.

The Millstone Grit reposing on the Carboniferous Limestone on the northern edge of the South Wales coal basin is remarkably like the Lower Cefn-y-Fedw Sandstone at Llangollen, and the Gower Shales much resemble the overlying series of shale, sandstone, and limestone at Holywell and Mold, in Flintshire.

In my former Papers read before this Society, and in "The Geology of the Country between Llanymynech and Minera," I proved the gradual termination of the main mass of the Carboniferous Limestone, and the overlap of the Upper Grey Limestone south of all the lower subdivisions. According to several sections of the

Geological Survey such an overlap is apparent on the north of the South Wales Coal basin. A section through the Carboniferous Limestone at Mynydd Garreg shows a thickness of about 550 feet; another section near Llandybie, about four miles from Llandeilo, 600 feet. A section at Carreg Llwyd shows a thickness of 500 feet, and another between Llandybie and Castel Craig Cennan 450 feet. That the limestone is thinner on the north of the Coal Basin is therefore quite clear, but the question is how the attenuation has been caused. From observations made at Llandybie I am inclined to the opinion, that only the upper beds of the Carboniferous Limestone occur on the northern limits of the Coal Basin, and that some of the lower beds are represented by the upper beds of the Old Red Sandstone; any unconformity between either the Millstone Grit and the Carboniferous Limestone, or between the limestone and the Old Red Sandstone is very improbable—neither is any such break shown on the Geological Survey Sections.

Mr. Woodward not only refers to the reduced thickness of the Carboniferous Limestone on the north side of the Coal-basin, but describes the area as a subsiding one, as proved by the successive overlapping of the strata from the Old Red Sandstone to the Coal-measures.

Finally I have arrived at the following conclusions:—

1st.—That the upper beds of the Carboniferous Limestone, on the north side of the South Wales Coal Basin, originally terminated against the Llandeilo and Bala beds, some miles *north* of their present outcrop, precisely as they do *south* in North Wales.

2nd.—That the lower beds of the limestone are represented by some of the upper beds of the Old Red Sandstone, as in North Wales, where red sandstone and

marl on different horizons appear below the successive subdivisions of the limestone.

3rd.—That the great central Silurian portion of Wales was never covered by the limestone, but that the Carboniferous sea extended along its western border, which accounts for the near resemblance of the formation in both North and South Wales.

NOTES ON THE WORKED FLINTS OF THE RAISED BEACHES OF THE N.E. COAST OF IRELAND.

By F. Archer.

After a reference to a communication made to the Society in the previous Session, the material facts of which are incorporated in the following paper, the Author proceeded:—

Raised beaches are to be found at different points of the Coast of Antrim and Down—for instance, at Carnlough, Ballygally, Larne, Kilroot, Bangor, and as far South as Dundrum—and at each of these localities, or in their immediate neighbourhood, Flint remains may be obtained. It is, however, at Larne and Kilroot that the connection between the raised beach and the Flint implements is closest, and can be treated as part of the study of Geology. At these places the amount of specimens indicating the presence of man in the Stone Age is very large, and the beaches are of great extent. That at Kilroot may be said to extend from the Whitehead, at the mouth of Belfast Lough, past Kilroot to Carrickfergus, and on, at intervals, towards Belfast, forming in some places a compact bank some eight to ten feet high of excellent Gravel, composed of Flint and Basaltic boulders, derived from the headlands of Whitehead. That at Larne is known as the

"Corran." It is in places fifteen feet in height, composed of similar materials to that at Kilroot, and projecting for about a third of a mile out into Larne Lough, with a breadth at the base of a quarter of a mile, thus forming to the west an inner bay, at the foot of which the town of Larne is situated, and to the east constituting a quay, alongside which vessels of the heaviest draft can come, and stretching out along the promenade to the point on which an ancient Castle is situated. In each case the beach is found to rest sometimes on the surface of the Boulder-clay and sometimes on the Estuarine silt, containing abundant shells and Foraminifera, which bears some resemblance to the blue silt with which we are familiar in the neighbourhood of Liverpool. This is very clearly shewn in a section behind the railway station at Larne Harbour, where an attempt has been made to manufacture bricks out of the Estuarine clay. In a section here, from west to east, we have near the Inner Bay a thin bed of small gravel covering the surface of the Boulder-clay, which here contains large masses of rolled Basalt, with Flint nodules and irregular pieces of the hardened Chalk of the neighbourhood. Crossing the road leading from Larne Harbour to the town, we see the Boulder-clay rising covered with a somewhat thicker bed of gravel, containing larger stones. About 150 yards further on in the same direction, along a new cross-road leading down to the shore of the Strait, at the entrance of the Lough, there occurs on either side a sudden rise and fall on the surface of the land, which consists of a sort of wave of rounded gravel, some of the stones being six inches across. This, in the direction of the railway station, is seen to spread out into a large and high mass of similar gravel, much of which has been carried off as ballast; and, in the other

direction, extends to the rising ground and rocks at the mouth of the Harbour. On examination of a longitudinal section of this wave of gravel to the left of the road, where the brickfield is situated, we find that it rests upon a thin bed of sand and fine gravel, containing many marine shells, which again rests on a bed of Estuarine clay or silt, also containing many marine shells or Foraminifera, and in which I found a large Flint flake, much discoloured by the nature of the clay in which it was situated, (possibly strayed from above.)

At Kilroot the beach in its main extension is situate on the Boulder-clay; while further west, near Carrickfergus, it is on the Estuarine Bed. It may be further observed that at Kilroot there is regular false bedding rising from west to east.

In both these localities, as before stated, the number of Flint flakes on the surface is enormous, and the conclusion is irresistible that these were the sites of manufactories, where, the raw material being in plenty, the flakes out of which arrow-heads, scrapers, and other larger implements were made, were roughed out. The condition of these rough fragments, however, is very puzzling. Most have their edges chipped, but in an incomplete way, as if by unskilful workmen; but still, it would seem, by human hands, and not by the effect of washing against one another. Others seem still more rough, and much worn, as if they had been subject to the action of the waves. It is not common to find here worked scrapers or arrow-heads, such as are found frequently elsewhere; but they do occur both at Kilroot and Larne.

I stated in my former observations that while at Kilroot last year I had an exceptionally good opportunity of examining the raised beach and its contents, as the

men were carting off many hundred tons of it, and laying it alongside the neighbouring railway for ballast. They first cleared away all the top soil, which contained many flakes, to a depth of about eighteen inches, thus leaving only apparently undisturbed gravel, and then took down the whole bank, some seven or eight feet in height. I was convinced by watching the men at work for some hours on successive days that many Flint flakes occurred in the lower part of the bank, and so stated to this Society. As, however, my friend Mr. Wm. Gray, of Belfast, who is the best authority on all matters connected with the subject, had expressed a strong opinion, derived from his long experience, that they were only found on the surface, or a few feet down where the gravel had been disturbed, I did not like to allow my view to be stated in print until I had confirmed my previous conclusion by a second examination. This I have now done with a satisfactory result. The men were not working while I was there this year, but had left a good perpendicular face for me to work at. I extract the following from my notes made at the time.

Friday, 1st October.—Borrowing a potato fork from a farm near, I made a good face, entirely removing the *talus* that had fallen since the men had been at work, at a central part of the bank, and examined the stuff as I felled it, and also the undisturbed face, with the greatest care and circumspection. I ultimately found and brought away twenty-eight specimens of flakes, cores, and fragments, all of which I extracted from the undisturbed gravel, and several of the most characteristic of them I picked out of the bank itself, before the stuff was felled, with my fingers, seeing the ends protruding. I also collected a number of marine shells associated with the Flints, which latter I marked "K" for identification,

Saturday, 2nd October.—I again visited the pit, and with my weapon I attacked the face opposite to that taken yesterday. Though I removed an equal quantity of material, I only found five specimens shewing human workmanship, a fact which may explain how it comes that careful observers have arrived at conclusions that the raised beaches do not contain Flint flakes. I, however, found many more marine shells than on the previous day; oysters, cockles, and periwinkles being very abundant, with other species not used for food.

I also examined the heap of ballast which had been carted to stand alongside the railway. In doing that, as I saw last year, the men first removed all the earthy upper layer, which contained many flakes, and which had no doubt been frequently disturbed in agricultural operations, leaving an undisturbed mass below, which was carted away just as it was, without being screened. Thus the ballast heap consists, in my opinion, of what was previously the undisturbed beach; I picked up on it a dozen excellent and characteristic cores, a few flakes, and a few marine shells, thus confirming my conclusions as above stated.

As will be seen on examination, the specimens obtained from the bank are exceedingly rude, and, with very few exceptions, inferior to the average of the specimens found on the surface, but they will in almost every case be found to possess all the requisites of the typical Flint flake and core, as given in Mr. Gray's compendious paper, entitled "The Character and Distribution of the rudely-worked Flints of the North of Ireland," extracted from "The Royal Historical and Archæological Journal" (4th series, vol. v., July, 1879, p. 6,) which I may here repeat,

A. The flat end; being a portion of the face of the Flint core from which the flake was struck.
B. The bulb of percussion, shewing the point that received the blow.
C. The conchoidal face as the result of the blow.
D. One or more ridges at the back.
E. The inclining surfaces or facets.

When I shewed these specimens to Mr. Robert McAdam, the learned Editor of "The Ulster Journal of Archæology," he exclaimed, "They look very much like the beginning of the manufacture."

It had been suggested by Mr. Gray that the false bedding at the Kilroot pit might indicate a reassortment of the materials of the beach by the stream of water which reaches the shore not far from it, in the same way as has occurred at Carnlough; this is, however, rendered highly improbable, if not disproved, by the presence in abundance of marine shells of several species associated with the Flint remains, which, as above stated, are unequally distributed throughout the mass, some species occurring much more abundantly in some parts of the pit than in others.*

I was not able to make a similar close investigation of the beach at Larne to what I have above described at Kilroot, though, from what I have observed, I have no doubt of a similar result; but we have the authority of Mr. Hull, of the Geological Survey, in his "Physical Geography of Ireland," to the effect that the raised beach of Larne is "composed of stratified and water-worn gravel, with numerous bleached marine shells, and flint flakes of human workmanship." He concludes from "the presence of worked flints, associated with the shells, in the

* A list of the Fossils of the Estuarine clay, by S. A. Stewart, will be found in Appendix ii. to the Proceedings of the Belfast Naturalists' Field Club, 1871. A list of those of the Raised Beaches of Larne and Kilroot is in the Report of the Belfast Meeting of the British Association in 1874.

stratified gravels at Larne and Kilroot, that the coast has been raised since the occupation of the British Isles by the ancient Celtic tribes." I think that a thorough and elaborate examination of the Corran at Larne, to ascertain the depth at which traces of human workmanship can be found there, should be made; and that the grant which was made by the British Association for the examination of the remains of the Stone Age generally in the North of Ireland, might with advantage be renewed for this special purpose.

It need scarcely be remarked how important a thorough knowledge of this point is in determining the question of the age of Man in Ireland. Up to the present time it is conceded on all hands that no deposits containing such palœolithic implements as have been discovered in several localities in England, as at Shrub Hill, Brandon Field, Canterbury, and Broome Hill, have been found in Ireland, and it is not claimed for the remains in the raised beaches that they are of so remote an epoch; still Mr. Hull refers to the Flints of Larne and Kilroot as "Palœolithic," and the occurrence of the specimens throughout a raised beach, the base of which, namely, the surface of Boulder-clay, is itself several feet above the reach of the highest spring tides, carries back the existence of man in Ireland to a somewhat far distance. I am not aware that any attempt has been made to gauge the rate at which the coast has been elevated or depressed; but it is a somewhat singular fact that on each of these two beaches at Kilroot and Larne a Castle was erected by King John, and it is thus certain that no material change whatever has taken place in the last 700 years.*

* See, however, "A Problem for Irish Geologists in Post-glacial Geology," by T. Mellard Reade, C.E., in the Scientific Proceedings of the Royal Dublin Society, for 1879.

The remainder of the paper consisted of notes on the Archæology of the Sandhill Settlements of the Stone Age, at Port Stewart, Ballintoy, Dundrum, &c. The paper was illustrated by numerous specimens.

The following List of Papers on the above subject is taken from Mr. Wm. Gray's Pamphlet:—

ROBERT DAY: Proceedings Kilkenny Archæological Society, Jan., 1865.
E. BENN: ,, ,, April, 1865.
W. GRAY: Belfast Naturalists' Field Club Report, April, 1867.
R. DAY: Proceedings Kilkenny Archæological Society, Oct., 1868.
J. EVANS: "Archæologia," Vol. xli., 1868.
G. V. DU NOYER: Journal Royal Geological Society of Ireland, 1868.
J. H. STAPLES: Belfast Naturalists' Field Club Report, 1869.
W. H. TRAIL: Geological Survey Memoir, Sheets 49 and 50, 1871.
W. J. KNOWLES: British Association Meeting, Belfast, 1874.
W. GRAY: ,, ,, 1874.
W. GRAY: Belfast Naturalists' Field Club Report, 1875.
PROFESSOR HULL: Geological Survey Memoir, Sheets 21, 28 & 29, 1876.
W. J. KNOWLES: British Association Meeting, Dublin, 1878.
W. J. KNOWLES: ,, ,, Sheffield, 1879.

NOTES ON THE SOUTHERN DRIFT OF ENGLAND AND WALES.

BY T. MELLARD READE, C.E., F.G.S.

THE following notes do not pretend to be more than passing records of observations made by the writer in various places in the Southern and Midland Counties and in South Wales, that he has from time to time happened to visit. But, though not the result of a systematic survey, the general bearings and relations of the facts have been kept steadily in view. These will be discussed in the concluding remarks to the extent such-like observations may warrant.

And here I must disabuse your minds of any idea that the title of this paper implies anything more than geographical distribution, although there are certain marked distinctions which will be explained between the Drift found in the South and that in the North of England.

ISLE OF PORTLAND.

In November, 1863, when examining the Chesil Bank, I was struck by the appearance of a section of what appeared to be Drift, at a point where the Chesil Bank dies into the Isle of Portland in the form of a beach. I produce a sketch of it such as I made at the time. The object of my visit being the examination of the pebble ridge, I had no time then to make further observations. My notes are to this effect: "It is a brown sandy sort of loam, full of irregular flints, and looks uncommonly like Boulder-clay; interstratified in it are a few bands of pebbles exactly like those of Chesil Bank."

In the Quarterly Journal of the Geological Society for Feb. 1875, is an elaborate paper by Professor Prestwich, entitled "Notes on the Phenomena of the Quaternary Period in the Isle of Portland and around Weymouth," and in it is a sketch of an "old land *débris*, with large boulders and seams of loess with land shells; cliff Chesilton," evidently a portion of the section I observed. Professor Prestwich devoted much more time to its examination than was at my disposal, but it is curious that no mention is made of the bands of pebbles similar to those in the Chesil Bank. I wrote to him on the subject, but he appeared indisposed to believe in their existence, as he had not himself observed them. Probably the section was in a different state when he saw it. At all events I am convinced of the accuracy

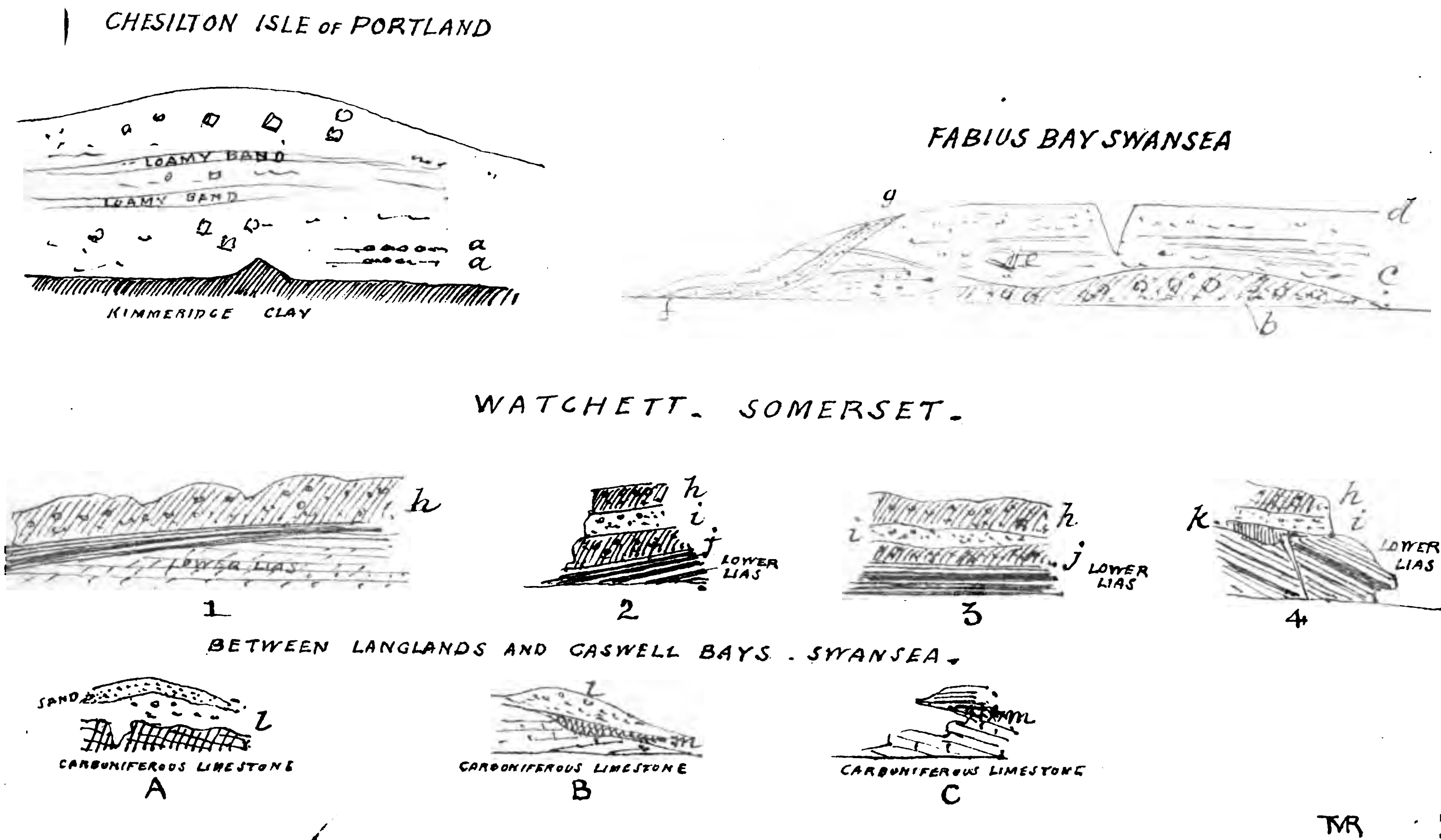
of my observations at the time, as I actually took out some of the pebbles from the face of the cliff, at *a a*, Plate 1, and brought them home. At a subsequent date I examined the same section, but could then find nothing but angular pieces of chert from the oolite embedded in it. On the same day I paid a visit to the raised beach at Portland Bill, with Prestwich's paper in my hand.

The raised beach consists of stratified gravel, shingle, and sand, cemented together into a conglomerate by carbonate of lime, derived doubtless from the oolitic rocks, and capped by a fine clayey sand, stratified. It lies on a low cliff of rocks overhanging the sea. Not far off, and over a quarry, I sketched another section consisting of calcareous sand, full of shells, with pieces of local rubble embedded therein, and covered with a bed of soil also containing marine shells. I noted it as remarkable that in the shell beds the stones were mainly local, and the flints interspersed among them were rounded; but when the beds were composed of flints the shells were absent. I found only subaërial clay soil or talus covering the beds. I formed the opinion that the pebbles were all marine, and had travelled there under ordinary conditions. No marks of ice action were to be seen. These beds of Drift do not occur like our Drift which covers the country, but only here and there, more like what is to be seen on the Macclesfield hills. From Weymouth to Lulworth Cove I observed none. There occurred nothing but subaërial remains of the chalk, a superficial bed lying on its surface. From Seaton to Lyme Regis I could discover nothing in the form of Drift.

PLYMOUTH.

The most remarkable feature of the country is the Hamoze, an inland water where men-of-war may be

PLATE I


CHESILTON ISLE of PORTLAND
LOAMY BAND
LOAMY BAND
a
a
KIMMERIDGE CLAY
FABIUS BAY SWANSEA
g
d
e
c
b
f
WATCHETT. SOMERSET.
h
LOWER LIAS
1
h
i
j
LOWER LIAS
2
h
i
j
LOWER LIAS
3
k
h
i
LOWER LIAS
4
BETWEEN LANGLANDS AND CASWELL BAYS . SWANSEA.
SAND
l
CARBONIFEROUS LIMESTONE
A
l
m
CARBONIFEROUS LIMESTONE
B
m
CARBONIFEROUS LIMESTONE
C
TMR

seen lying at anchor. It is really a southern fjord, evidently the result of a depression of the valley of the Tamar. On the Hoe are the remains of a raised beach. We find in patches shells and shell fragments cemented together with carbonate of lime, lying upon Devonian limestone; in some places it consists of pebbles and angular fragments; there is also a good deal of angular cover lying upon it. I visited the raised beach at the Hoe with a party of geologists from the British Association. Some of them thought they could discover traces of glacial action on the limestone: there were no striations, but smoothed hollows. I never yet saw any glacial markings take this form. I attribute the surface form of the rocks to chemical action of water acting under the superficial covering of Drift.

THE CHEESEWRING, CORNWALL.

About 7 miles from Liskeard, in a subaërial cover forming the downs, are large boulders of trap. When we approach the granite district the subsoil is composed of very coarse grains of decomposed granite, and embedded among it are very large blocks and boulders, also of granite. How these large boulders have been transported, or produced, does not seem quite easy of explanation. The Cheesewring in itself is a most striking object in appearance, consisting of a series of circular cushions of granite piled on each other (see Sketch, Plate 2). It stands as if to shew the extent of the denudation which has taken place since the last submergence; for we cannot help inferring that these blocks have been subaërially weathered out of the granitic mass. But we must not forget to notice that some of this granite decomposes rather rapidly; for I noticed in the Parish Church at Plymouth, where granite

and limestone have been used together in the dressed work, that the limestone stands the better of the two.

DARTMOOR.

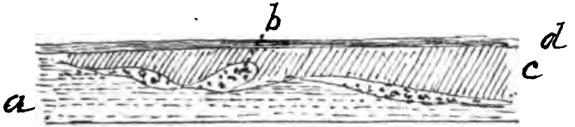
From Bickleigh to the Dewar Stone the locality is very beautiful; wooded glades, with ferns and mosses in profusion, giving delightful glimpses and vistas. The dark chocolate-coloured waters of the stream, enlivened by white foam, and bordered by luxuriant vegetation, is very refreshing to the artist's eye, or to any one appreciating colour. As far as the object of the present paper is concerned, the only remarkable things are the remains of granite boulders scattered about, and the evidences of denudation to be seen on all sides.

WATCHETT.

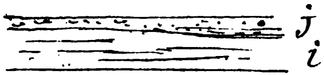
Between the Isle of Portland and Watchett, on the British Channel, there is but little Drift to be seen. In the cuttings of a railway, between Midsummer Norton and Shepton Mallet, I observed some Drift covering up the irregular tilted edges of the Carboniferous limestone in one place, consisting of clay, but containing no stones. At Wells, on more than one occasion, I have observed by the Great Western Railway Station, a Drift composed of angular and sub-angular stones, embedded at all angles, some with their axes vertical, consisting of Carboniferous, Devonian, Triassic, and Liassic rocks. At Westbury I observed an alluvial clay, but with no stones, overlying the iron sands, worked from the surface by the Westbury Iron Company. Crossing the Quantock Hills, from Crowcombe to Watchett, we find they are singularly free from rock exposures, being smoothed off with a coating of angular detritus and subaërial marl. There are very few rounded stones to be seen, and no

PLATE 2

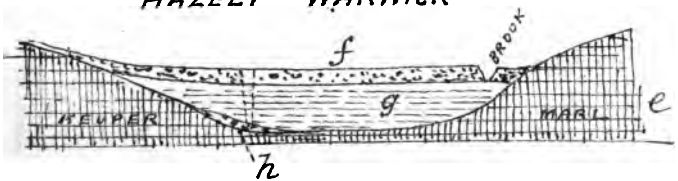
FINCHLEY



BRICK EARTH GRAYS THURROCK



HAZELY WARWICK



THE CHEESEWRING

evidences of submergence. At Watchett we come upon the only true Boulder-clay that I have seen in Somerset. It lies at the top of the Lower Lias cliffs, exposed to the Bristol Channel. I sketched sections at four points. The first (Fig. 1, Plate 1) shows red clay (*h*), containing rounded stones, mostly Devonian. The second (Fig. 2) consists of three beds, the middle one being of shingle (*i*), and the lower (*j*) red clay, with stones at all angles. The third (Fig. 3) shews the same arrangements of beds, with seams of fine clay in the lower one, and fewer stones. The whole is about 18 feet thick, according to my notes. The fourth (Fig. 4) consists of shingle (*i*), lying on the upturned edges of the Lias, with a patch of yellow clay (*k*) below it, on the left-hand side of a fault, and capped by red clay. The lower clay contains pebbles of Lias limestone, as well as Devonian sandstone. If there were erratic or travelled pebbles among the shingle, they must have been proportionally small in number. I noticed no scratches on the stones. The material of the clay has, no doubt, been derived from the Triassic marls which exist in the neighbourhood.

Where the Midford Sands exist, as at Yeovil in Somerset, the valleys are V-shaped and deep, and having been subject to great denudation, retain no traces of Drift, if it ever existed there.

SWANSEA.

On the opposite side of the Bristol Channel is Fabius Bay, Swansea. A section of Boulder-clay is to be seen which may naturally connect itself with that just described at Watchett, though it bears more traces of being a glacial deposit. I give a section of it. The bedding is irregular, distorted, and thrown about in a manner those who have studied glacial Drifts are

familiar with. The lower bed of clay Plate 1 (*b*), contains many rounded boulders; lying upon this is rudely stratified gravel and shingle (*c*), in inconstant beds. A large angular block of "Pennant" stone, (*e*), lies embedded in it, and capping the cliff at *d*, is angular and subangular gravel. A band of buff-coloured clay runs across the section at *f*, *g*.

It is very difficult to describe the sections in a way for others to realize without seeing them; the bedding is so formless and inconstant as to be impossible to classify.

In Langland Bay, lying on the Carboniferous Limestone, is a deposit of subangular Drift and waterworn pebbles. (1, Plate 1, Fig. *a*.) Between Langland and Caswell Bays, lying on the cliffs, is a sort of concrete of limestone "Macadam;" it is a very singular deposit. At another point this (bed M, Figs. *b* and *c*) is capped by a Drift formed of sub-angular and rounded boulders (*l*, Fig. *b*). These deposits seem to be synchronous with the raised beaches of Portland Bill.

LANDORE.

I merely mention this place as a striking instance of the denuding power of rain when the subsoil is not protected by vegetation. The fumes from the Copper works have destroyed all vestiges of grass, the result being that the subsoil has been washed away, and the surface cut up and corroded with ramifying gutters.

ISLE OF WIGHT.

The surface of the chalk is covered over in places with a superficial deposit containing flints, but this has evidently been derived from the subaërial destruction of the chalk. Nothing of the nature of true Drift was to be seen at any of the places I visited.

FINCHLEY.

The glacial beds of Finchley have been well described by Mr. Searles Wood, Mr. Walker, and others. In November, 1873, I examined the deposit which occupies what is called the north London glacial plateau, and is interesting, as being one of the few deposits really entitled to be ealled glacial about London. I give a section of a gravel pit as I sketched it at the time. The bottom bed (*a*, Plate 2), so far as exposed, is of yellow stratified sand, the surface having the appearance of being irregularly eroded. Upon this lies a discontinuous bed of flint gravel (*b*), the centre part shewn in section having the appearance of being bent over in a fold. Lying upon this is a brown clay (*c*), with blue marblings, and containing few stones. Mr. Walker informed me this was not considered to be Boulder-clay. This is capped with surface soil (*d*), with flints at the base, lying immediately on the clay. At Plowman's Manor brickfields the clay contains numerous fragments of chalk *débris*, and is full of fossils denuded from the chalk and lias. One of the men told me that a well sunk in the neighbourhood 45 feet deep, showed 30 feet of this clay with blue clay (London clay?) below, and that the clay got bluer in colour as the bottom was approached. I found a scratched limestone boulder. Erratic stones, such as trap and Old Red sandstone, are found in it; but I was not fortunate enough to detect any. Mr. Searles Wood places this clay under "the great purple clay" of Yorkshire; but to an eye accustomed to Northern Drift the glacial characteristics of this clay seem but slight.

A list of extraneous materials taken out of this Boulder-clay was kindly supplied me at the time by Mr. Walker. The largest boulder, which was of diorite, measured only 8 in., by 5 in., by 4 in.

THAMES VALLEY.

The superficial deposits of the Thames Valley have so often been described by geologists long familiar with them, among which are Mr. W. Whittaker, F.G.S., the late Professor Phillips, and Professor Prestwich, that I feel it would be impertinent on my part, from the cursory examinations I have made, to say much on the subject. Still, to enable you to realize, if possible, their relations to the northern glacial beds, I will describe what I have seen. At Grays Thurrock I examined the brick-earth and I give a section of the face of the excavation. (Plate 2.) The brick-earth (*i.*), of which about 5 feet was seen, is a dark yellowish brown loam, containing occasional flints and bands of calcareous matter. The upper bed (*j.*) is about 3 feet thick, a sort of alluvial clay with flints. There was nothing organic to be seen in this section. The bricks made from it are not very good, and vary in colour from a yellowish brown to red. I noticed in a burned brick, on another field, what I have never before seen in clay that has gone through a kiln—the shell of a gasteropod, its shape being perfectly preserved. The bricks also contained specks of glassy matter, hollow and of a brilliant blue.

The level of this brick-earth is above that of the present river, and there is decided evidence of very considerable denundation having taken place since it was laid down.

The Geological Survey shews what are called glacial gravels in the Thames valley, but I had not the good fortune to see any of them. The general appearance of the country about the Thames, if we except what is called the Thames gravel, is more remarkable for the absence than presence of Drift deposits. There were none in the Thanet sands where I have seen them, nor in a walk

from Caterham to Godstone, or about Chiselhurst, did I perceive a trace of anything of the kind. In the neighbourhood of Gravesend I noticed some sand and gravel beds; but unfortunately I cannot describe them, as my notes are mislaid. I shall have to refer to the observations of others in my reasonings on these deposits.

Commencing again in South Wales, I will now try and trace some of the Drift deposits up into the Midland counties.

EBBW VALE.

In this valley is to be seen, along the hill sides, a yellow clay containing angular, sub-angular, and rounded boulders. They appear to be mostly from local rocks. Some of the boulders are remarkably well rounded, which is the more striking as being mixed with so much angular *débris*. With the exception of the rounded boulders, the arrangement of the Drift of Chesilton, in the Isle of Wight, is not unlike it. It is rather a conflicting mixture of materials, puzzling, like many of these deposits.

LEDBURY.

A section of gravel Drift is to be seen at Newtown, near Ledbury. The gravel contains a good many fossils from the Silurian rocks, and I am told by a geological shoemaker in the neighbourhood, that the tooth of a Mammoth, 11 lbs. in weight, was found in a similar gravel near Ledbury.

WARWICK.

During the construction of the Hasley Waterworks, carried out by Mr. E. Pritchard, Engineer, to supply the town of Warwick with water, I had an opportunity of seeing a section of the Drift gravels and sand of the neighbourhood. The valley lies in the Keuper Marls—

(*e*), Plate 2—as shewn in the section. There is, commencing from the surface (*f*), about eight feet of gravel and shingle, the pebbles mostly of quartzite, varying in colour from white to nearly black, some being purple. Some of it looked like the quartzite of Harts Hill. I noticed one piece of volcanic ash, and a few flints, and what appeared to be Carboniferous sandstone. Mr. Pritchard shewed me some erratic boulders, including granite, he had picked out during the progress of the work. There appears to have been a Drift of materials from the various quarters of the compass. I noticed no striated or flattened stones. Below this bed is a white and yellow siliceous sand (*g*), barren of shells or other organic remains. Near the bottom of the trench excavated for one of the drains, about 25 feet deep, another bed of gravel (*h*) was come upon, but it existed only in patches. Mr. Pritchard has since informed me that a large glaciated erratic was also found. There is argillaceous matter mixed with the upper gravel.

The water supply is taken out of this sand bed (*g*) by means of deep drains.

The Drift of Warwickshire generally is of the nature of that just described. Near Kenilworth Station is to be seen a considerable development of this gravel.

REVIEW OF THE PRECEDING OBSERVATIONS.

The preceding observations, necessarily disconnected from being made at various times during the last eight years, as the opportunities presented themselves, I fear contain rather an uninteresting repetition; but I have no desire to render the descriptions more palatable by drawing upon the imagination. I fear enthusiasts, of which there are many in this branch of geology, sometimes unintentionally do so.

To an observer from the north, the most striking thing in the whole of the sections I have described of the Southern Drift is the absence of those features he usually considers accompany glacial deposits. If we leave out of account South Wales and Watchett, there is only Finchley that presents any symptoms of what even by courtesy may be called "glacial action." Here in Lancashire we have undoubted evidence in the large planed and grooved erratics that are almost everywhere to be found, in addition to every other boulder, and many pebbles being distinctly marked in the same way. There is no mistaking the evidences, yet some geologists tell us that our beds are "reconstructed," not true glacial; while others urge, on grounds that I cannot but consider purely theoretical, that such beds as those at Finchley are older than ours. It seems to be considered more respectable to have an ancient glacial deposit than a *parvenu* young one!

Again, another feature that strikes the northern geologist, is the exceedingly small development of these deposits as he travels south. The East coast deposits do not fall within the scope of this paper, nor have I yet seen them.

Without going into details, if I may be permitted to take a comprehensive survey of this question with the materials at my disposal, I would point out that, as a general rule, the glacial deposits are in greatest force in the lower valleys of the mountain districts and the plains surrounding them. This applies equally to Scotland, Ireland, England and Wales. It is also worthy of notice that the markings, commonly considered to be evidences of glacial action, are found also in these areas—indeed, are confined to them. The smoothed, rounded, and striated rocks are the first features that

were noticed in connection with former glacial action, and these are universally in the proximity of mountain districts. The groovings we find on the rocks under our marine Boulder-clay of Lancashire and Cheshire are those, so far as I know, the farthest removed from the mountain areas; but when we get further south these cease, though there are rocks of identical nature and equally capable of retaining striations to be found elsewhere. The further off the mountains, also, as a rule, the fewer the erratics and the smaller. To a geologist studying the Drift of the midland and southern counties, it is no wonder if these beds give him, as they did Buckland, the impression of diluvial action—of the action of floods of water rather than of transfer by ice. Depend upon it, these old-fashioned first ideas contain some portion of truth—perhaps quite as much as the more complicated and new-fangled explanations that are afterwards adopted and applied. Our besetting sin is that we are constantly pushing theories to extremes; each discoverer of some new thing, like the inventor of a patent, thinks his machinery adequate for anything it can be put to do. No doubt it is; but then the question arises, was it ever put to do it? I know I am speaking dreadful heterodoxy; but I consider that those geologists who, to explain the glacial period, gather up the waters of the ocean about either pole, so as even to displace to some extent the centre of gravity of this spheroid, are not one whit more reasonable than the old-fashioned catastrophists, who explained every apparent break in sequence by mighty convulsions destroying all life.

"The Geology of Oxford and the Valley of the Thames," that excellent work by the late Professor Phillips, contains a very good account of the superficial gravels and deposits within the drainage basin of the

Thames. It will not do for me here to repeat in detail what he says; but he divides the gravels into hill or high level gravel containing stones brought from a distance, and valley or low level gravel, consisting mostly of rocks due to the valley itself. He says, p. 458: "These hill gravels are composed of materials which it is impossible to suppose to have been drifted at any time or under any circumstances by water flowing as a river, or inundation from atmospheric precipitations: the extent of ground occupied and the nature of the pebbles and fragments imply the agency of wide ocean streams mostly directed from the northward to the southward. A marine origin is thus found for the hill gravels; but I am not aware of any modern reliquæ of the sea being found in them within the drainage of the Thames, though ancient fossils are common enough in particular places. Floating ice has been suggested as the vehicle of the transport of these extra Tamisian stones, and their geological date is expressed by the term 'glacial,' the valley gravels being universally admitted to be 'post glacial.'"

I am quite prepared to accept Phillips' explanation. I have seen innumerable sections of Drift in various parts of the country that do not contain even the particle of a marine shell, that, nevertheless, I am convinced are the result of sea action. It is extremely probable that subaërial action has since destroyed all traces of their origin. It does not require any great research to establish the fact that the deposits as a rule thicken as the mountain areas are neared. For instance, although there are the Keuper Marls in Warwickshire to supply the material, there exists in that county no deposit of Boulder-clay such as we have in Lancashire and Cheshire. I was struck

with the absence of Boulder-clay in Warwickshire, and its replacement with sand and gravel. Level, no doubt, has a great deal to do with the prevalence and development of these glacial deposits, as I hope to prove more fully at some future time. A glance at my sections will shew that the deposits in the south-west, having any pretensions to be called glacial, when away from the mountains lie very near the sea level.

It is difficult to take a connected view of all the Drift phenomena; but I have seen no evidence yet pointing clearly to more than one uninterrupted glacial period and one submergence. The Southern Drift is only what we might expect to result from sea action with occasional floating ice, modified since by being exposed to continuous subaërial influences. The shingle and gravel most probably was principally distributed by tidal and wind currents. The almost universal roundness of the pebbles points to this. There are other causes to be considered, which I can hardly bring forward, much less treat of in this paper, influencing the distribution of the Boulder-clay; but I have collected a body of facts in this neighbourhood, which I hope to put into order soon, that may throw some light upon this question.

Deposits of angular *débris*, such as that of the Isle of Portland, invariably occur near to high ground. Professor Prestwich accounts for these by sudden re-emergence of the land creating diluvial action, by which the materials are washed off the sides of the hills and deposited at the base before the stones have a chance of being rounded. The explanation does not commend itself to my mind. It appears to me, notwithstanding his elaborate arguments to the contrary, to be simply in the nature of talus, and land wash that has in many

cases come within reach of the sea.* I agree with him that most probably it has been formed during emergence, but slowly, and also since by gradual accretion and by land slips. This phenomenon of angular *débris* is not confined to the south of England, but occurs also to a greater or less extent in most true glacial deposits that lie against steep hill sides. But much of this angular *débris* is certainly posterior to the glacial period, and I take it as an evidence of a great lapse of time since that period during which subaërial action has gone on, constituting a proof of its antiquity.

If from the South Coast we direct our attention to the extreme North of Scotland, we find from the wonderfully graphic pictures of the Boulder-clay sections in Robert Dick's Letters to Hugh Miller, as given in Smiles' biography of Dick—a work that should be read by all geologists—that a deposit very different to any I have described covers much of the County of Caithness.† It would appear from his descriptions, that the Boulder-clay there is more nearly of the nature of "Till" than is our marine Boulder-clay; that it is more stony, and composed of the grindings of the adjacent rocks. I have but lately read these letters, and was much struck by the graphic power and intelligence they display. Further, they go towards strengthening my convictions as to the origin of "Till," as expressed in my paper on the "Glacial beds of the Clyde and Forth," I had the honour to read at this Society last session; which views were further expounded in a paper I contributed to the Glasgow Geological Society on "The Relations of the Glacial

* Those wishful to know more of this deposit should read Mr. Prestwich's very excellent paper, already referred to.

† It has been described by many geologists, but none enable us to form so clear an image of its nature as do Dick's word pictures.

Beds of the Clyde and Forth to those of the North-West of England."

It would appear to me that the apparently diluvial deposits of the middle and South of England are the result of subaërial re-arrangement, denudation, and attrition of the deposits laid down during the same period that produced our marine Boulder-clays and the Scotch fossiliferous and unfossiliferous Till. The deposits have been thinner; they have been spread over a larger area of country, so that everything has conduced to favour their alteration and re-arrangement. Though the rainfall is less, excepting in Cornwall, than it is in the north of England, the *quantity* of rain is more, from the greater area receiving it, consequently the rivers are larger. In North Wales and in Scotland the mountain streams entering the sea are choked with rounded boulders and gravel, also, I believe principally the result of denudation of glacial deposits. But these phenomena, from the configuration of the land, are confined to the narrow valleys, while in mid-England the rivers are larger, slower, and wider, and here the deposits naturally are more spead over the country; while those on the plateaus, no doubt, have had their materials first rolled by the sea, and then their lighter materials subaërially washed out of them.

As regards the raised beaches surrounding our coasts, it is difficult to fix their relative position in time. Most probably those I have described near the Mumbles are synchronous with that of the Bill of Portland; the levels are much the same.

What I have laid before you are merely a few facts I have gleaned from time to time, and suggestions that occur from them. I do not feel myself yet in a position, even if I ever am, to set forth anything more than a very

general idea of the distribution of glacial and other Drift in time and space, even in England. I have no faith in those minute classifications which of late years have come into fashion, depending on the perfection of all the links of a complicated theory, any one of which proving defective — and few being to my mind established beyond cavil—the whole theoretical structure falls to the ground. Let us try and place the theory of what is called Glacial Geology on a firm basis of fact. To do this we must establish each position carefully step by step, and not in eagerness for discovery jump at conclusions that we are compelled at last regretfully to abandon, or else stick to with a persistence savouring more of obstinacy than inductive science.

NOTES ON THE STRATA AND WATER-LEVEL AT MAGHULL.

By Isaac Roberts, F.G.S.

Maghull is situate about six miles to the north-north east of Liverpool, and the position to which these notes refer is in latitude 53° 30′ 28″ north, and 2° 55′ 58″ west longitude, and is distant five miles from the sea.

Maghull, and the country around it, may be considered as a plain 55 feet above mean sea level, for at no place within a radius of four miles from the point indicated above is there a patch of ground covering an area so large as half a square mile, at a much higher altitude.

The lowest land within a radius of four miles are Sefton meadows, which are about 22 feet above mean sea level.

The strata about Maghull are Upper Mottled Sandstone, with here and there a covering of Lower Keuper Sandstone; and at Melling, which is distant a mile to the south-east of Maghull, is a small outlier of Bunter Pebble Beds, which are quarried for building purposes. This outlier has been much disturbed, as shewn by the faults, fractures, and trough-fault, within a small area exposed in the quarry.

Three years ago I had occasion to supply my house with water, and following is a description of the mode which I adopted to obtain it.

The Upper Mottled Sandstone, which here lies 2 feet below the surface of the ground, and 62 feet above mean sea level, was bored with a hole, 6 inches in diameter, to the depth of 48 feet below the surface.

Within the bore-hole, a continuous tinned Iron pipe, 5 inches in diameter was placed, and the annular space between the pipe and the rock was filled with Portland cement. After the cement had hardened, the bore-hole (reduced to 4 inches in diameter), was continued to the depth of 27 feet below the bottom of the iron pipe, or 75 feet below the surface of the ground. The water then rose up in the pipe to within 11 feet of the surface. It will thus be seen that any percolation of water from the surface is prevented from entering the bore-hole, until it has filtered through at least 48 feet of solid rock, for the water can only enter the bore-hole by the lower 27 feet of rock.

In sinking the bore-hole 6 or 7 thin seams of red shale were met with, two of them in the lower 27 feet, and therefore the water, as it is pumped from the hole, is slightly turbid, but after filtration it is sparkling and agreeable to the palate.

Analysis shows the water to contain sulphates, but no nitrates or chlorides.

The permanent hardness in degrees per gallon, or in 70,000 parts, is	7·5
Temporary hardness	5·5
Total	13·0

After filtration the total hardness is 11·5 degrees.

The yield of the bore-hole, or quantity of water that can be pumped out of it in a given time, was tested by continuous pumping by two men for a day, when it was found that they could only lower the water surface 10 feet, and if they ceased pumping for a short time the water rose to the normal level. Present investigations which I am engaged upon show that the normal water level varies considerably, and I expect after long continued observations, to be able to trace the effect of its cause or causes. The locality is well adapted for these investigations, for there are no local disturbing causes, such as exist in other localities, where a large supply of water is abstracted from the rock by pumping.

The temperature of the water as it emerges from the pump is remarkably uniform—it remains constant at 50° Fahrenheit.

Three months ago I had occasion to obtain a supply of water for domestic purposes, at a house distant one and a half miles to the north-north-west from my house, and following is a section of the strata:—

	FT.	IN.
Surface Soil	1	6
Fine Sand	7	6
Boulder-clay	2	0
Coarse Gravel and Pebbles	1	2
Boulder-clay	13	10
Coarse Gravel and Pebbles	0	10

	FT.	IN.
Boulder-clay	5	0
Lower Keuper Sandstone	40	2
Total depth	72	0

The rock is uniformly hard, of a cream colour, and without any seams of shale.

Following is analysis by Dr. Campbell Brown of the water obtained from the well:—

Total solid matter in solution in 100,000 parts	27·4
Organic Carbon; „ Nitrogen	small quantities.
Ammonia	·02
„ from Organic Matter by distillation with Alkaline permanganate	·014
Combined Chlorine	3·55
Hardness—moderately high.	

The normal level of the water in the well is 5 ft. 8 in. below the surface of the ground, which is 48 feet above mean sea level.

My objects in bringing this subject before the Society are to give a glimpse below a surface that is covered with superficial deposits, which are not often removed to show what is beneath them, and also to show the large supply of water that is yet available for domestic uses lying within, and by percolation replaced in, the pores of the rock which covers many square miles of this part of the country. Had the boring experiment, which was tried at Bootle, been tried about Maghull, the promoters of that experiment would have had at least a temporary triumph, and might have delayed the introduction of a more comprehensive scheme for supplying Liverpool with water for some years to come; but I am not suggesting that the triumph would have been beneficial or profitable to the ratepayers, nor permanent in its character.

LIST OF PAPERS

ON

THE GEOLOGY OF THE COUNTRY AROUND LIVERPOOL.

FROM 1870 TO JUNE, 1881, WITH SOME ADDITIONS TO THE LIST PUBLISHED IN 1871,

BY G. H. MORTON, F.G.S.

ADDITIONS TO THE LISTS PUBLISHED IN 1869-70.

1810.

CAMPBELL, DR.—"Remarks upon the Inferior Strata of the Earth occurring in Lancashire, with some Miscellaneous Observations arising from the Subject," with a coloured Geological Map of the County, by Dr. Wilkinson. —*Letters and Papers on Agriculture, Planting, &c. Selected from the Correspondence of the Bath and West of England Society*, 1810.

In a review of "The Progress of Geological Research in connection with the Geology of the Country around Liverpool," in the *Geol. Mag.*, Vol. ix., p. 87, Mr. H. B. Woodward remarks:—"This is probably one of the earliest attempts to illustrate the Geology of the county of Lancashire."

1847.

CHAMBERS, R., F.R.S.E.—*Ancient Sea-Margins*, p. 223.

Contains a description of the successive platforms, or terraces, on both sides of the Mersey, and gives the heights and situations. A woodcut represents the terrace on the bank of the Mersey at Seacombe.

1859.

Hull, E., B.A., F.G.S.—"On the New Subdivisions of the Triassic Rocks of the Central Counties."—*Trans. Manc. Geol. Soc.*, Vol. ii., p. 22.

Gives a minute description of the subdivisions of the Trias, and the sections around Liverpool where each may be examined. The paper is illustrated by a lithographic section, showing "Ideal Section of the Trias of Cheshire," &c., and a table "Showing the relative thickness of the Triassic sub-formations." The great source of all these sedimentary strata was from the north and west.

1865.

Hull, E., B.A., F.G.S.—Geological Survey of Great Britain.—*Horizontal Section*, Sheet 68.

Drawn from Little Eye Island in the Estuary of the Dee, on the west; to Horwich Moor, Lancashire, on the east; by Birkenhead, Liverpool, Croxteth and Knowsley Parks, Billinge Beacon, and the Wigan Coal District; showing Triassic and Carboniferous Formations.

1865.

Hull, E., B.A., F.G.S.—Geological Survey of Great Britain.—*Explanation of Horizontal Section*, Sheet 68.

LIST FROM 1870 TO JUNE, 1881.

1869–70.

Morton, G. H., F.G.S.—Anniversary Addresses by the President, with a List of Papers on "The Geology of the Country around Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 11th and 12th.

In these two addresses there is a list of previous papers on the geology of the country around Liverpool, with explanations and critical remarks, up to the date of the last, October, 1870.

1870.

BOULT, J., F.R.I.B.A.—" Speculations on the former Topography of Liverpool and its Neighbourhood."—Part iii., *Proc. Lit. & Phil. Soc., L'pool,* Vol. xxv., p. 11.

Origin of names of places. Origin and former condition of the Mersey and its tributaries, with remarks on the submarine forest at Leasowe.

1870.

BOSTOCK, R.—" The Mersey and Dee—their former Channels and Changes of Level."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 11th, p. 41.

Shows the improbability of several supposed outlets of the Mersey and Dee, and concludes that there has not been any change in the course of either river.

1870.

CARRUTHERS, W., F.R.S.—" Remarks on the Fossils from the railway cutting at Huyton."—*Nature*, Vol. ii., p. 527.

Short description communicated to the British Association.

1870.

DE RANCE, C. E., F.G.S.—" Notes on the Geology of the Country around Liverpool."—*Nature,* Vol. ii., p. 391.

Gives general Geological description of the district, for members of the British Association.

1870.

EARWAKER, J. P.—" Geological Discovery in Liverpool."—*Nature,* Vol. ii., p. 397.

Describes insect remains found at Ravenhead, St. Helens, associated with numerous ferns.

1871.

De Rance, C. E., F.G.S.—"On the Pre-Glacial Geography of Northern Cheshire."—*Geol. Mag.*, Vol. viii., p. 158.

Describes the pre-glacial form of the land and the plains bordering the sea. The Mersey was then a tributary of the Dee, and flowed from its present course, opposite Liverpool, westward, between the Bidston and Wallasey hills, entering the Dee opposite Mostyn—close to the mountains of Wales.

1871.

Higgins, H. H., M.A.—"On some Specimens, supposed to be Fossils of a Plant named Pycnophyllum (Brong. and Schimp.) in the Ravenhead Collection of Fossils, Free Public Museum, Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 12th, p. 71.

A plate with the paper represents the scars and ducts as seen on a compressed stem 4 inches in diameter. Concludes that the leaves grew in large tufts on a stock, or very short stem.

1871.

Morton, G. H., F.G.S.—"Minerals that occur in the neighbourhood of Liverpool, with the localities, &c."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 13th, p. 92.

Gives a list of 15 Minerals found in the Triassic sandstone and Coal-measures in the immediate neighbourhood of Liverpool.

1871.

Morton, G. H., F.G.S.—"Shells found in the Glacial Deposits around Liverpool, with the Localities, &c."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 13th, p. 91.

List of 23 species of Mollusca, found by Dr. Ricketts, F.G.S., Mr. Isaac Roberts, F.G.S., the Author, &c., being all observed to the date of the paper.

1871.

ROBERTS, I., F.G.S.—"Effects produced by Red Sandstone upon Salt Water."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 12th, p. 66.

Further analyses to prove that much of the water obtained from the wells in different parts of Liverpool is derived from the sea, and that the salts held in solution are gradually increasing in quantity. Gives analysis of water from a well in Rainford Square in proof.

1871.

ROBERTS, I., F.G.S.—"Section of Boulder-clay at the Gas Works, Linacre, Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 12th, p. 68.

List of Shells from the Boulder-clay at Linacre. The number found of each species is given, so that the relative abundance is shown. A bed of sand divides the Boulder-clay into two beds—the lower being the most compact, and containing a larger number of stones.

1871.

READE, T. M., C.E., F.G.S.—"The Geology and Physics of the Post-Glacial Period, as shown in the Deposits and Organic Remains in Lancashire and Cheshire."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 13th, p. 36.

Contains a very full description of the Coast between the Dee and Ribble. The Post-Glacial deposits are minutely described, as well as the area they cover. A large coloured map, and numerous sections in illustration of the deposits are appended. A copious Appendix, describing the sections, is an important addition to the text.

1872.

HIGGINS, H. H., M.A.—"On some Fossil Ferns in the Ravenhead Collection, Free Public Museum, Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 13th, p. 94.

General remarks on the fossil ferns collected by the author and described by Mr. Marrat. No traces of fructification discovered, though an examination of rejected specimens was made.

1872.

Hull, E., F.R.S,, F.G.S.—"On a Remarkable Fault in the New Red Sandstone of Rainhill, Lancashire."—*Jour. Royal Geol. Soc. Dub.*, Vol iii., (New Series) p. 73.

————"Further Observations on the Well, St. Helens, Lancashire."—*Jour. Royal Geol. Soc. Dub.*, Vol. iii, p. 86.

In sinking for water the fault described was found to hade so considerably, that another bore-hole became necessary. Only one fault with such a great angle known in England—two horizontal to one vertical.

1872.

Mackintosh, D., F.G.S.—"The Age of Floating Ice in North Wales—Sea-coast Fringe of mixed Local and Northern Drift."—*Geol. Mag.*, Vol. ix., p. 15.

Although referring principally to North Wales, there are frequent references to Lancashire and Cheshire.

———— "Correlation of the Scotch and English Drifts."—*Geol. Mag.*, Vol ix., p. 190.*

Gives the usual general section of the Drift in the north-west of England and part of Wales.

1872.

———— "On a Sea-Coast Section of Boulder-clay in Cheshire."—*Quar. Jour. Geol. Soc.*, Vol. xxviii., p. 388.

Describes the threefold division of the Drift deposits along the Cheshire side of the Dee. The Upper Boulder-clay underlain by extensive and persistent deposits of non-glacial sands and gravel, which repose on the Lower Boulder-clay. Each of the clays is minutely described, and in some places coalesce. The Lower Boulder-clay is the hardest, and contains 15 species of Mollusca.

---

*Letter on "Calcareously-incrusted Stones in Drift," by the same author, at page 144.

1872.

Marrat, F. P.—"On some Fossil Ferns in the Ravenhead Collection."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 13th, p. 96.

Gives a list of 62 species of ferns from Ravenhead, of which eight are new species, and were named by Mr. Marrat. Thirteen lithographic plates contain the new species, and many of the most interesting species previously described.

1872.

Morton, G. H., F.G.S.—"The Strata below the Trias in the Country around Liverpool; and the probability of Coal occurring at a moderate depth."—*Proc. Lit. & Phil. Soc., L'pool,* Vol. xxvii., p. 157.

Gives sections showing the Coal-measures thrown up against the Bunter Pebble-beds, proving the continuation of the former below the Trias. The thickness of the Pebble-beds 350 feet, and the base along line of Shaw-street fault. Supposed coal might be found at the depth of 2,000 feet.

1872.

Reade, T. M., C.E., F.G.S.—"Glacial Striæ at Miller's Bridge, Bootle, Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 14th, p. 31.

1872.

Reade, T. M., C.E., F.G.S.—"The Post-Glacial Geology and Physiography of West Lancashire and the Mersey Estuary."—*Geol. Mag.*, Vol. ix., p. 111.

An abridgement of the paper with a similar title, read before, and printed in the *Proc. L'pool Geol. Soc.*, 1871, all re-written, except the final conclusions, which are the same.

1872.

Roberts, I., F.G.S.—"Section of Strata above the Boulder-clay at Whitechapel, Liverpool."—*Proc. L'pool Geol. Soc.*, Vol ii., Sess. 14th, p. 32.

Roberts, I., F.G.S.—"The Excavations in Whitechapel, Liverpool."—*Proc. Lit. & Phil. Soc., L'pool*, Vol. xxvii., p. 57.

Gives section of Peat and Blue-clay, resting on Boulder-clay.

1873.

Boult, J., F.R.I.B.A.—"The Mersey as known to the Romans."—*Proc. Lit. & Phil. Soc., L'pool*, Vol. xxvii., p. 249.

Examines the evidences in support of Dr. Ormerod's opinion, that the upland waters of the Mersey formerly flowed through Wirral into the Dee. Gives numerous reasons for supposing that the estuary of the Mersey was a fresh-water lake during the Roman period, and that the outlet opposite Liverpool was formed by the tides in the 13th century.

1873.

De Rance, C. E., F.G.S., and Reade, T. M., F.G.S. "Cyclas and Scrobicularia Clays of the South-West of Lancashire."—*Geol. Mag.*, Vol. x., pp. 139, 187, 238, 288.

Correspondence on the Marine or Freshwater character of the beds; giving the conclusions of the authors more fully than in their respective papers.

1873.

Mackintosh, D., F.G.S.—"Observations on the more remarkable Boulders of the North-West of England, and the Welsh Boulders."—*Quar. Jour. Geol. Soc.*, Vol. xxix., p. 351.

Principally describes districts beyond the Liverpool area; but there is a reference to the Lower Boulder-clay at Dawpool. A map illustrates the distribution of Boulders in the North-West of England, including Lancashire and Cheshire.

1873.

Reade, T. M., C.E., F.G.S.—"The Buried Valley of the Mersey."—*Proc. L'pool Geol. Soc.*, Vol. ii., Sess. 14th, p. 42.

Numerous borings in many localities, proving the depth of the rock from the surface. Informed that usually there are more stones in the lower clay. Directs attention to the frequent occurrence of pebbles lying on the rock. Speaks of evidences of the country having been covered by an ice-cap in Glacial times, and that the Mersey was widened and perhaps deepened by the passage of such ice over it.

1873–80.

Reports of the committee appointed for registering the Erratic Blocks and Boulders in the United Kingdom."—*Rep. Brit. Assoc.*, Vols. xliii–l.

Contains notices of large boulders in the country around Liverpool, by G. H. Morton, F.G.S., Vol. xlv., p. 82. Boulders at Dawpool and Bootle, by D. Mackintosh, F.G.S., Vol. xlvii. p. 82, and Vol. xlxix., p. 138.

Section of Lower and Upper Boulder-clay, by G. H. Morton, F.G.S., Vol. xlvi., p. 110. Describes section at new docks, Bootle, near Liverpool. Sand and Silt—Old Bootle Shore; Upper Boulder-clay; Sand and Gravel; Lower Boulder-clay. The middle Sand and Gravel often thin out and leave the Upper Boulder-clay reposing on the Lower-clay. Site of excavation reclaimed from the shore within the tidal range.*

1874.

Boult, J., F.R.I.B.A.—"The Deterioration of the Mersey."—*Trans. Hist. Soc. of Lanc. and Ches.*, Vol. xxvi., p. 29.

Describes scouring power of the water through the narrow entrance of the river. Clay cliffs along the banks rapidly wasting away, and the principal source of the silt in suspension. The probable amount of sediment is indicated.

---

* Also described in the *Geol. Mag.*, Vol. xiii., p. 526. Letters on the section will be found in the same volume, by Mackintosh at p. 429-528; Reade, 480; and again in Vol. xiv.,—Reade, at p. 38; Mackintosh at pp. 94 and 575.

1874.

Reade, T. M., C.E., F.G.S.—"The Glacial and Post-Glacial Deposits of Garston and the Surrounding District, with Remarks on the Structure of the Boulder-clay."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 19.

Describes Ground Moraine, a local deposit at Garston. Continuous deposit of the Low Level Marine Boulder-clay and Sands. Sand and gravel frequent in the sections of Boulder-clay. Most stones toward the base. Species of shell-fragments described. Character and proportion of erratic stones and boulders. Post-Glacial beds.

1874.

Reade, T. M., F.G.S.—"On the Drift-beds of the North-West of England. Part I, Shells of the Lancashire and Cheshire Low-level Boulder-clay and sands."—*Quar. Jour. Geol. Soc.*, Vol. xxx, p. 27.

Gives typical section of Low-level Boulder-clay and sand at Bootle Lane Station. Ice-sheet striated rock surfaces. A break occurs between the formation of the striæ, and the deposition of the Boulder-clay described. No older beds than the Low-level Boulder-clay had been found. Mode of occurrence and range of Mollusca described, and list of 44 species given in table, with numerous references.

1874.

Shone, W., F.G.S.—"On the discovery of Foraminifera, &c., in the Boulder-clay of Cheshire."—*Quar. Jour. Geol. Soc.*, Vol. xxx., p. 181.

Adheres to Mr. Mackintosh's arrangement of the drift clays of Cheshire, which he considers a most accurate, full and exact account of the lithological and stratigraphical description of the beds. Foraminifera occur in both the Upper and Lower Boulder-clay, but more fossilized in the latter.

1875.

De Rance, C. E., F.G.S.—"On the Relative Age of some of the Valleys in the North and South of England, and of the various and Post-Glacial Deposits occurring in them."—*Proc. Geol. Assoc.*, Vol. iv., p. 221.

Describes Glacial and Post-Glacial Drifts of South-West Lancashire, and gives wood-cut section from Southport to Ormskirk, showing Boulder-clay and more recent deposits.

1875.

POTTER, C.—"Observations on the Geology and Archæology of the Cheshire shore."—*Trans. Hist. Soc. of Lanc. and Ches.*, Vol. xxviii., p. 121.

Gives a section of the Lower Forest-bed, and superior beds of peat, silt, and sand. Stumps and trunks of the embedded trees deposited in water with the peat, as now seen. No appearances of rootlet have been observed.

1875–80.

"Reports of the Committee appointed for investigating the Circulation of Underground Waters in the New Red Sandstone."—*Rep. Brit. Assoc.*, Vols. xlv.–l.

Contain much information respecting water supply and strata around Liverpool. "On the South Lancashire Wells," by T. M. Reade, F.G.S., Vol. xlvii., p. 56. "Rainfall at Sandfield Park, Lancashire," 1865–74, by Mr. Briggs, Vol. xlvii., p. 81. "Strata penetrated by the Bootle Bore-hole," by C. E. de Rance, F.G.S., Vols. xlviii., xlix., l. "Experiments on the Filtration of Sea-water through Triassic Sandstone," by Isaac Roberts, F.G.S., Vol. xlviii., p. 397. "Report on the Water in the Triassic sandstone at West Kirby, Cheshire," by Isaac Roberts, F.G.S., Vol. xlix., p. 159. "Section of Trias down to the Coal-measures," by C. E. de Rance, F.G.S., Vol. l., p. 87.

1875.

BOULT, J., F.R.I.B.A.—"An Enquiry into the Source of Water in the New Red Sandstone." (Parts 1 and 2.) —*Jour. L'pool Polyt. Soc.*

Gives a valuable table showing the position and yield of water of the numerous wells around Liverpool. The paper contains a large amount of information on the local water supply, and in the account of the discussion the opinions of many others are given.

1876.

DAWKINS, W. BOYD, M.A., F.R.S., F.G.S.—"On the water supply in the Red Rocks of Lancashire and Cheshire."—*Trans. Manc. Geol. Soc.*, Vol. xiv., p. 133.

Gives a table, showing the thickness of the subdivisions of the Trias in Cheshire and Lancashire, and describes the condition under which the water is stored up in the strata. Refers to faults; the amount of percolation; and suggests that deep wells would increase the supply.

1876.

De Rance, C. E., F.G.S.—"On the Variation in Thickness of the Middle Coal-measures of the Wigan Coal-field."—*Rep. Brit. Assoc.*, Vol. xlvi., p. 89.

Wigan Coal-field not merely a synclinal of subsidence, but one of deposition. Coal-measures are thinner at Prescot than at Wigan, and thinner still at Burnley.

1876.

Reade, T. M., C.E., F.G.S.—"The Formby and Leasowe Marine Beds, as shown in a section near Freshfield."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 120.

Gives section near Formby Hall, and refers to mammalia bones with shells found there and elsewhere in corresponding beds.

1876.

Reade, T. M., C.E., F.G.S.—"Glacial Striations at Little Crosby."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 241.

1876.

Whitaker, W., B.A., F.G.S.—"List of Works on the Geology, Mineralogy, and Palæontology of Cheshire."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 127.

A chronological arrangement adopted, ending with the year 1873, when the publication of the *Geological Record* began.

1877.

De Rance, C. E., F.G.S.—"Memoirs of the Geological Survey of England and Wales."—*The Superficial Geology of the Country adjoining the Coasts of South-West Lancashire.*

POST-GLACIAL DEPOSITS.

Describes Modern Marine deposits and blown sand, Roman and other antiquities bearing on the Geology of the district, Estuarine clays, Peat mosses and submerged forests, Shirdley Hill Sand, Lower Scrobicularia and Cyclas Clays, particularly at the mouth of the River Alt, of which a section is given.

Describes Physical Geography, and sequence of Geological Events;—Moraines—*Glaciers* in N. Wales and Lake district, and deeper valleys of Pennine Hills. Upper Boulder-clay—*Coast-ice*, drift from the North-west. Middle Drift Sand—*Tidal-currents*, local drift. Lower Boulder-clay—*Sea and ice-foot*, drift from the North-west. Till—Lower Moraine Drift, *large glaciers and ice-sheet.*

The only sections described in the Liverpool area are at Preston-road Station, and Litherland Bridge and Gas Works, both Upper Boulder-clay with interstratified bed of sand.

The Lower Boulder-clay in the Valley of the Mersey never forms the surface, and only occurs at the base of deep cliffs, or valley sections. It is seldom met with in excavations, and no exposure of the Lower Boulder-clay near Liverpool is given, but it is assumed to underlie the Upper Boulder-clay. Striated surfaces described. List of shells, 43 species, in the Lower Boulder-clay in the Liverpool area, and 90 species in Upper and Lower, including surrounding counties and North Wales.

1877.

De Rance, C. E., F.G.S.—"On the Correlation of certain Post-Glacial Deposits in West Lancashire."—*Rep. Brit. Assoc.*, Vol. xlvii., p. 68.

Denudation of the Boulder-clay from the Valley of the Mersey to that of the Ribble, followed by the deposition of beds of sand, peat, and silt.

1877.

De Rance, C. E., F.G.S.—"On the variation in thickness of the Coals and Measures of the Lancashire Coalfield."—*Trans. Manc. Geol. Soc.*, Vol. xiv., p. 207.

Describes a number of Colliery sections from Prescot—through Wigan—to Burnley, being an explanation of the Vertical Section, No. 61, of the West Lancashire Coal-field by the Geol. Survey. The sections show the gradual decrease in thickness of the Coal-measures along the line of country referred to, and much information is given respecting the Millstone Grit, and the numerous important faults which fracture the Coal-measures.

1877.

Mackintosh, D., F.G.S.—"On a number of New Sections around the Estuary of the Dee, which exhibit Phenomena having an important bearing on the origin of Boulder-clay and the sequence of Glacial Events."—*Quar. Jour. Geol. Soc.*, Vol. xxxiii., p. 730.

Notices the straight or undulating line of junction between the Upper and Lower Boulder-clays, along the shore of the Dee. Describes the Boulders and mode of occurrence. Confirms the observations of Mr. De Rance, F.G.S., as to the section of Upper and Lower Clays at Egremont Ferry. The Lower Boulder-clay at the New Dock sections, near Bootle, is harder than the Upper Clay, and a section shows the three divisions originally described by Mr. Morton, F.G.S. Describes a similar section at Birkenhead. Materials of the Lower Clay used-up in the accumulation of the Middle Drift, which, however, has frequently in its turn been denuded.

1877.

Morton, G. H., F.G.S.—"The Glacial Striæ of the Country around Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 284.

Contains a Table showing the great variation in the direction of the striæ on the sandstone around Liverpool. Rocks striated early in Glacial period by floating ice. Upper and Lower Boulder-clays deposited in deep water, but the middle sands and gravels indicate an interval when shallow water prevailed.

1877.

Ricketts, C., M.D., F.G.S.—"The Conditions existing during the Glacial Period, with an account of Glacial Deposits between Tranmere and Oxton, Cheshire."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 245.

Glacier in the Valley of the Mersey, and a tributary one in the Happy Valley. Describes moraine accumulations, and gives very minute details. Boulder-clay formed by the degradation of local rocks, and embedded stones deposited from icebergs.

1878.

DAWKINS, W. BOYD, F.R.S.—Review of "The Superficial Geology of South-West Lancashire."—*Nature*, Vol. xviii., p. 561.

No important physical difference between the Upper and Lower Boulder-clays; lenticular beds of sand and gravel intercalated here and there in the Boulder-clay. Considers the large size of trees in peat bogs may be accounted for by the shelter afforded in a primeval forest.

1878.

DE RANCE, C. E., F.G.S.—"On the Lancashire Coal-Fields."—*Proc. Geol. Assoc.*, Vol, v, p. 389.

Describes the Millstone Grit and Coal-measures, but particularly of the south-west of Lancashire.

1878.

DE RANCE, C. E., F.G.S., and STRAHAN, A., B.A., F.G.S.—Geological Survey of England and Wales. *West Lancashire Coal-Field. Sections of Shafts sunk in the Middle Coal-measures of Prescot, St. Helens, Wigan and Burnley.*

The Arley Mine is adopted as the datum line, and the sections are drawn on the scale of 100 feet = 1 inch. Sections at ten collieries are given and an Index Map shows the position of each.

1878.

MACKINTOSH, D., F.G.S.—"Results of a Systematic Survey in 1878 of the Direction and Limits of Dispersion, Mode of Occurrence and Relation to Drift-deposits of the Erratic Blocks, or Boulders of the West of England and East of Wales; including a Revision of many Years' Previous Observations."—*Quar. Jour. Geol. Soc.*, Vol. xxxv., p. 425.

Describes dispersion of boulders over a large portion of the west of England and North Wales, illustrated by a large map. Refers to Upper and Lower Boulder-clays, and "striated pavement" at Dawpool. Striated surfaces around Liverpool and Birkenhead, covered by Upper Boulder-clay, and both clays deposited by means of floating ice. No evidence of the existence of land-ice.

1878.

Morton, G. H., F.G.S.—"Notice of Drift-beds observed in sinking for water at Aughton, near Ormskirk."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 370.

Section of Upper Boulder-clay, gravel and sand. Five feet of "Stoney Boulder-clay" near the bottom closely resembled the Lower Boulder-clay observed in the excavations at the North Docks, and described *Rep. Brit. Assoc.*, Vol. xlvi, p. 112.

1878.

Reade, T. M., F.G.S.—"The Submarine Forest at the Alt Mouth."—*Quar. Jour. Geol. Soc.*, Vol. xxxiv., p. 447.

Describes the digging out and uprooting of one of the stools of the trees in the presence of several witnesses, with particular description of it—the object being to prove that the trees had grown on the spot where they now occur.

1878.

Reade, T. M., C.E., F.G.S.—"Some further notes on the Submarine Forest at the Alt Mouth."—*Proc. L'pool Geol. Soc.*, Vol. iii., p. 362.

Describes roots and stools of trees in various stages of decay. Remains of trees of successive growth, and at varying distances apart. A swamp, or bog, succeeded the forest. Replies to Messrs. Boult and Potter, who argue that the trees are not in situ.

1878.

Reade, T. M., C.E., F.G.S.—"On a Section through Glazebrook Moss, Lancashire."—*Quar. Jour. Geol. Soc.*, Vol. xxxiv., p. 808.

Gives a minute description of the peat-moss through which the railway was excavated. Numerous stools of trees in their original position, broken off near the base. Some prostrate trunks, 46 and 60 feet in length. The peat rests on Boulder-clay.

1878.

Reade, T. M., C.E., F.G.S.—"The Trees of the Post-Glacial Forest Beds in the neighbourhood of Liverpool."—*Trans. Hist. Soc. of Lanc. & Ches.*, Vol. xxx., p. 27.

Another account of the digging out of the stool of a tree at the Alt mouth, in the presence of several witnesses, and finding numerous rootlets, indicating growth in situ.

1878.

Ricketts, C., M.D., F.G.S.—"On some Remarkable Pebbles in the Boulder-clay."—*Proc. L'pool Geol. Soc.*, Vol. iv., p. 10.

1879.

————"On some Remarkable Pebbles in the Boulder-clay of Cheshire and Lancashire."—*Rep. Brit. Assoc.*, Vol. xlix., p. 339.

Erratic pebbles, ice-marked and otherwise eroded, abundant in the Boulder-clay of Lancashire and Cheshire. Some have been weathered under exceptional circumstances, probably in moraines on land, and afterwards carried away by icebergs and were deposited in the Boulder-clay.

1879.

Shone, W., F.G.S.—"On the Glacial Deposits of West Cheshire, together with Lists of the Fauna found in the Drift of Cheshire and adjoining Counties."—*Quar. Jour. Geol. Soc.*, Vol. xxxiv., p. 383.

Stratigraphical portion relates principally to the three drifts exposed near Chester, though Dawpool is referred to. Gives lists of the Mollusca, Ostracoda and Foraminifera from the Drift in various localities in Cheshire, Lancashire, Salop, and N. Wales, after correcting the errors in the list of shells in the Survey publication. Most of the shells referred to the Lower Boulder-clay by Mr. De Rance, are given as Upper Boulder-clay.

1879.

BROWN, J. C., D. Sc., F.C.S.—"Analyses of Rocks from the 1,300 feet deep Bore-hole at Bootle."—*Proc. L'pool Geol. Soc.*, Vol. iv., p. 63.

Gives analyses of one specimen of sandstone forming the Pebble beds, and two of the Lower Bunter.

1879.

DE RANCE, C. E., F.G.S.—"Notes on some Triassic Borings."—*Trans. Manc. Geol. Soc.*, Vol. xv., p. 90.

1880.

DE RANCE, C. E., F.G.S.—"Further Notes of Triassic Borings near Warrington."—*Trans. Manc. Geol. Soc.*, Vol. xv., p. 388.

Contain journals of several important borings, including Dallam Lane Forge, Warrington, and Winwick. A description of the boring at Bootle, and a reference to one at Parkside.

1881.

HULL, E., LL.D., F.R.S.—"South Lancashire Coal field."—*The Coal Fields of Great Britain*, 4th Ed., Chap. xiii.

Contains a description of the South Lancashire Coal field. Sections of strata at St. Helens and Wigan, lists of the fossils, and a Map of the Coal-field.

1881.

PHILLIPS, J. A., F.G.S.—"On the Constitution and History of Grits and Sandstones."—*Quar. Jour. Geol. Soc.*, Vol. xxxvii., p. 6.

Results of microscopic examination of several Triassic sandstones in the neighbourhood of Liverpool, including the millet-seed beds, which the author considers to have been derived from blown sand.

1881.

READE, T.M., C.E., F.G.S.—"The Date of the last Change of Level in Lancashire."—*Abs. Proc. Geol. Soc.*, No. 402, p. 64.

States that the land is now gaining upon the sea. Calculates the rate at which the sand at Blundellsands accumulates. Concludes that there has been no recent subsidence of the coast of South-west Lancashire.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
EDWARD W. BINNEY, F.R.S., F.G.S., Douglas, Isle of Man.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D.Sc., Queen's College, Galway.
JOHN W. JUDD, F.R.S, F.G.S., London.

MEMBERS.

ADDISON, W. H., Deaf and Dumb Institute, Oxford Street.
ARCHER, F., B.A., Boundary Cottage, Crosby.
14, Cook Street.
BARRETT, W. S., Winton Lodge, Victoria Road, Great Crosby.
*†BEASLEY, H., Acre-field House, Woolton.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
BRAMALL, H., 3, Balmoral Road.
BROWN, C. H., Low-wood, Alexandra Road, Southport.
*BROWN, J. CAMPBELL, D.Sc., F.C.S., 27, Abercromby Square.
COOGAN, P. M., C.E., 28, Green Lawn, Rock Ferry.
DAVIES, C., 8, Kinglake Street, Edge Hill.
DODD, J., 2, Derby Terrace, Rock Ferry.

DOWEN, Z. T., Rev., 20, Oriel Road, Bootle.
* † ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackin's Hey.
FITZPATRICK, M., 62, Seel Street.
FITZPATRICK, J. J., 62, Seel Street.
† FOSTER, E., 7, Newstead Road, Smithdown Lane.
FOSTER, R. M., 34, Oxford Road, Waterloo.
GREEN, A., York House, Old Chester Road, Rock Ferry.
9, Canning Place.
GRIFFITHS, J., 4, Exton Park, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B., Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W., B.Sc., 67, White Rock Street.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport.
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
LEA, T., Vale Cottage, Huyton Quarry.
LEIGH-GREGSON, S., Aigburth Road.
Slater Court, 5, Castle Street.
LIGHTBODY, J. H., Birchfield, Sefton Drive.
*MACKINTOSH, D., F.G.S., 32, Whitford Road, Higher Tranmere.
*McCLAY, J. L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MAYER, J., F.S.A., Pennant House, Lower Bebington.
*MOORE, T. J., C.M.Z.S.L., Newsham Drive, Newsham Park.
Liverpool Museum.
*MORGAN, ALFRED, 2, Rathbone Terrace, Wellington Road, Wavertree.
26, North John Street.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I. (Hon. Secretary), 10, Sheil Road. 122, London Road.
†MOTT, C. G., Sunnyside, Cavendish Road, Birkenhead.
McMILLAN, A., Conway, North Wales.
PATERSON, J., Palmyra Street, Warrington.
PEARSE, W., 21, Harrington Street.
Green Bank Farm, Wavertree.
*† PICTON, J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.

*POTTER, C., 101, Miles Street.
PEARSON, J. E., Golborne Park, near Newton-le-Willows.
QUILLIAM, W. H., 49, Rufford Road, Fairfield.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Holt Hill, Tranmere.
ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
*SEMMONS, W., 57, Gracechurch Street, London, E.C.
STONE, R., Jun., Newton Park, Newton-le-Willows.
STRONGITHARM, G., 77, Whetstone Lane, Tranmere.
SPARGO, E., Bangor, North Wales.
SHERLOCK, C., 63, South John Street.
TIMMINS, A., C.E., Mill House, Runcorn.
VEEVERS, S., Huyton.
WILSON, W. H., St. Michael's Hamlet, Aigburth.
31, Wapping.
WRIGHT, B. M., F.R. Hist. Soc., 90, Great Russell Street, Bloomsbury, London.
WARD, T., Northwich, Cheshire.
WARD, J. R., 57, Garth Road, Bangor, North Wales.
YOUNG, H. (Hon. Treasurer), 12, South Castle Street.

ASSOCIATES.

MORGAN, Mrs., 2, Rathbone Terrace, Wellington Road, Wavertree.
MORTON, Miss, S.E., 10, Sheil Road, Elm Park.
ROBERTS, Mrs., Kennessee, Maghull, Lancashire.

* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-THIRD.

1881-2.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART IV.—VOL. IV.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1883.

OFFICERS, 1881–2.

President.

DANIEL MACKINTOSH, F.G.S.

Vice-President.

ISAAC ROBERTS, F.G.S., F.R.A.S.

Ex-President.

WILLIAM SEMMONS.

Honorary Treasurer.

EDWARD W. HANCE, LL.B.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

ALFRED MORGAN.
FREDERIC P. MARRAT.
T. MELLARD READE, C.E., F.G.S.
CHARLES RICKETTS, M.D., F.G.S.
HENRY BEASLEY.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

Advocates' Library, Edinburgh.
Belfast Naturalists' Field Club.
Birkenhead Free Public Library.
Do. Literary and Scientific Club.
British Museum.
Bristol Naturalists' Society.
Bodleian Library, Oxford.
Boston Society of Natural History, U.S.
Chester Society of Natural Science.
Dudley and Midland Geological and Scientific Society.
Epping Forest and County of Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Geological Magazine."
,, "Nature."
,, "Science Gossip."
Geological Survey of Belgium.
Geological Society of Edinburgh.
Geological Society of Glasgow.
Geological Survey of India.
Geological Society of London.
Geological Society of Manchester.
Geological Survey of the United States.
Geological and Polytechnic Society of the West Riding of Yorkshire, Leeds.
Geological Association, Liverpool.
Geologists' Association, London.
Glasgow Philosophical Society.
Hayden, Dr., United States.
Koninck, L. G. de., Prof., Liege.

Leeds Philosophical and Literary Society.
Liverpool Athenæum.
,, Chemists' Association.
,, Free Public Library.
,, Geological Association.
,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
,, Polytechnic Society.
L'Universite Royal de Norvège, Christiana.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal D'Histoire Naturelle de Belgique.
Museum of Practical Geology.
North of England Institute of Mining and Mechanical Engineers.
Orleans County Society of Natural Science, Vermont, U.S.
Owens College, Manchester.
Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
Smithsonian Institution, Washington, U.S.
Société Geologique de Belgique, Liege.
Société Geologique du Nord, Lille.
Toscana Societa di Scienza Naturali.
University Library, Cambridge.
Warwickshire Natural History and Archæological Society, Warwick.
Watford Natural History Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-THIRD.

OCTOBER 11TH, 1881.

THE PRESIDENT, DR. J. CAMPBELL BROWN, F.C.S., in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been audited by Mr. ISAAC ROBERTS and Mr. HENRY BEASLEY.

The following papers were then read:—

NOTICE OF THE RECENT FALL OF AN AËROLITE NEAR MIDDLESBROUGH, YORKSHIRE.

By G. H. MORTON, F.G.S.

The Author described the fall of this Aërolite, and read an account of it, by Prof. Herschel, in the "Newcastle Daily Chronicle," March 30th, 1881. The Aërolite, and the earth containing the hole it made in falling, were exhibited at the Meeting of the British Association, at York, in the same year. Since that time, a full account of it has appeared in the "Report of a Committee, on Observations of Luminous Meteors during the year 1880-1." Appendix II.—On the Fall of an Aërolite near Middlesbrough, Yorkshire, March 14th, 1881, by A. S. Herschel, M.A., F.R.A.S.—"Rept. Proc. Brit. Assoc.," p. 296. An exhaustive description having appeared in a work of such easy reference, the Author considered it superfluous to repeat it here.

THE OCCURRENCE OF SOME LOW ISLANDS IN THE CARBONIFEROUS SEA.

By Charles Ricketts, M.D., F.G.S.

NOVEMBER 8th, 1881.

The President, DANIEL MACKINTOSH, F.G.S., in the Chair.

Hopkin Thomas was elected an Ordinary Member.

The following paper was read :—

TRACES OF AN INTERGLACIAL LANDSURFACE AT CREWE.

By Daniel Mackintosh, F.G.S.

DECEMBER 13th, 1881.

The President, DANIEL MACKINTOSH, F.G.S., in the Chair.

George Tate, Ph.D., F.G.S., F.C.S., was elected an Ordinary Member.

Mrs. T. Mellard Reade was elected an Associate.

The following papers were read :—

ON A SECTION OF THE FORMBY AND LEASOWE MARINE BEDS AND SUPERIOR PEAT BED, DISCLOSED BY THE CUTTINGS FOR THE OUTLET SEWER AT HIGHTOWN.

By T. Mellard Reade, C.E., F.G.S.

THE LAND SUBSIDENCES IN THE SALT DISTRICTS OF CHESHIRE AND THEIR CONNECTION WITH THE MANUFACTURE OF SALT.

By Thomas Ward.

JANUARY 10TH, 1882.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following paper was read :—

THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF FLINTSHIRE. THE COUNTRY TO THE SOUTH OF MOLD.

By G. H. MORTON, F.G.S.

FEBRUARY 14TH, 1882.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following paper was read :—

ON THE BASE OF THE NEW RED SANDSTONE IN THE COUNTRY AROUND LIVERPOOL.

By G. H. MORTON, F.G.S.

MARCH 14TH, 1882.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following paper was read :—

A GEOLOGIST'S NOTES IN NORFOLK AND SUFFOLK.

By T. MELLARD READE, C.E., F.G.S.

TRACES OF AN INTERGLACIAL LAND-SURFACE AT CREWE.

By D. Mackintosh, F.G.S.

During a number of visits to Crewe Railway Station in 1879-80, I had opportunities of examining sections and specimens of an exceedingly fine and (when damp) more or less flexible kind of book or leaf-clay. They were exposed in excavations for underground passages and drains. I did not see the bottom of the leaf-clay, but Mr. Andrews (assistant engineer) informed me that he had seen it resting on quicksand. The clay, within a vertical extent of about a foot, graduated into very typical and undisturbed upper Boulder-clay, about ten feet in thickness.

This leaf-clay is evidently on the same horizon as numerous similar deposits which may be seen in many parts of Cheshire and Lancashire, at or towards the base of the upper Boulder-clay, and which range as low down as the present sea-level. In many places these deposits show ripple-marks of a kind which must have been formed in very shallow water, though I did not see any ripple-marks on the clay at Crewe Railway Station.

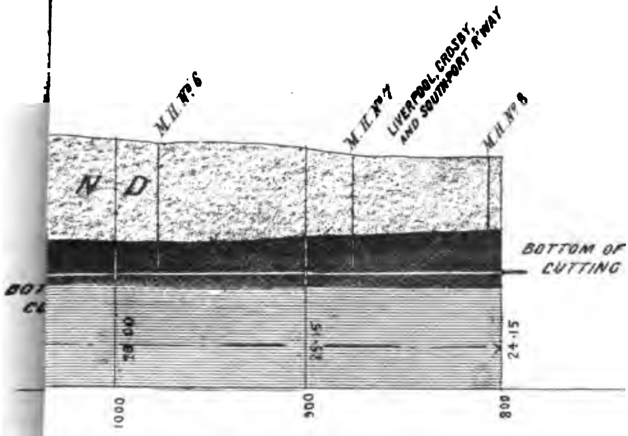
The leaf-clay under notice is the finest of any yet examined by the well-known foraminiferist, Mr. Siddall, of Chester, who found in it a shallow or brackish-water species of Foraminifera, namely, *Polystomella striato-punctata.* The laminæ of which the clay is composed are generally very thin, but they can easily be separated, owing to an intervening sprinkling of sand, which, at intervals, may have been distributed by shallow currents of water, or blown by wind *(see sequel).*

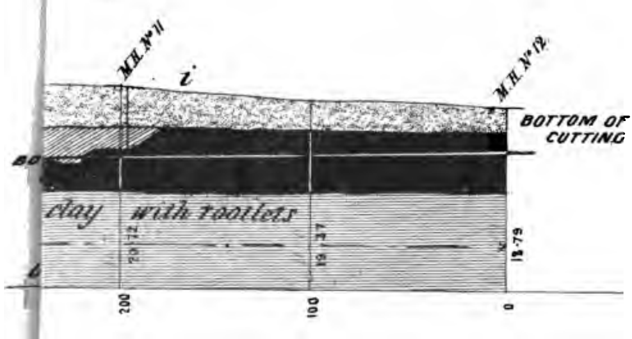
One of the most striking features of the leaf-clay is the extent to which the surfaces of the laminæ are pitted. I have little doubt that some of the pits (especially those steeper on one side than on the other) were produced by rain when the surfaces of the laminæ were above water; but in most instances they can be better explained by supposing the escape of imprisoned bubbles of air; and Mr. Siddall believes that he has seen a confirmation of this theory of their origin in experimenting with the clay while dissolved in water contained in glass bottles.

Clay, very similar to that found under Crewe Railway Station, may now be seen in course of accumulation along the shores of some parts of the estuary of the Mersey, and more especially in the back-waters of the Menai Strait; and Mr. Siddall is of opinion that the Crewe leaf-clay was deposited within the tidal range; but while believing that it may have been partly formed between high and low water, I have seen very similar clayey laminæ with intercalated sprinklings of sand, and pits left by air-bubbles (besides rain-pits) at some distance from the sea. Around Birkenhead (and I have no doubt elsewhere), at the bottom of excavations made for obtaining clay for making bricks, rainwater, assisted by wind, has produced a laminated clay very similar, in the respects already named, to that found under Crewe Railway Station, with the addition of marks (in the Birkenhead excavations certainly, and at Crewe probably,) left by the crawling of worms.

During his microscopic examinations of the Crewe leaf-clay, Mr. Siddall found the débris of plants, including rootlets, one of which certainly was in the position in which it grew, as it extended through the clayey laminæ in a direction at nearly right angles to the planes

raling silt,- e. pelvis of horse.





sand (bones of dog)- i. old warren wall.

OF FEET

300 OF FEET

of lamination; in other words, it occupied a position in which a drifted specimen could not well have remained had the laminæ been accumulated around it by currents of water.

From all the above facts and considerations, I think it may be regarded as highly probable, if not certain, that in Cheshire, the land before the commencement of the submergence which accumulated the upper Boulder-clay, with its intensely striated stones, stood at a level not much lower than it does at the present day.

ON A SECTION OF THE FORMBY AND LEASOWE MARINE BEDS AND SUPERIOR PEAT BED, DISCLOSED BY THE CUTTINGS FOR THE OUTLET SEWER AT HIGHTOWN.

By T. Mellard Reade. C.E., F.G.S., F.R.I.B.A.

This Section commences at a point on the banks of the River Alt, about 1,300 feet below the floodgates. The mouth of the outlet sewer is about four feet above Ordnance Datum, from whence it rises, in a distance of 70 feet, to eight feet above Ordnance Datum. It then continues at a uniform gradient at 1 in 400 across the railway at Hightown Station, and along the highway called Sandy Lane, a total distance of 2,303 feet. At the present moment, November 2, 1881, the sewer has been laid nearly up to the railway, and the cutting extends a short distance along Sandy Lane.

It will be seen from this description that the cutting would prove a crucial test as to whether, and if so, in what way, the submarine Peat and Forest-Bed is con-

nected with the inland exposure of peat, as I have stated it is, in my "Post Glacial Geology of Lancashire and Cheshire."*

In laying the outlet pipes in the river bank from A to B, only blue, slutchy clay was met with; but in a side trench made for draining the main trench at a depth of 3 feet 6 inches, and lying upon a bed of sand, human remains were found, consisting of the lower jaw containing four grinders, the left humerus, and the right radius.

No peat was met with until about 140 feet of trench was opened, when it came in as a feather edge; the first part lay upon hard sand, but at manhole No. 2 it was 2 feet 6 inches thick, and lay upon "Scotch" or blue silt, which was excavated into 5 feet. Beyond this, tree stumps were embedded in the peat. The peat then thinned out until it was nearly lost, and here it was upon hard, white sand. The level at this point was about 15 feet above Ordnance Datum. The peat here thickened out suddenly, and at manhole No. 3 an oak stump was taken out. At 18 feet further along, where the water was stanked up, the peat, with roots of trees below washed clean by the run of water out of the trench, was very prettily displayed.

At 30 feet beyond manhole No. 3, two small pieces of bone were taken out from between the peat and the underlying sand. Mr. Moore says they are fragmentary pieces of the pelvis of horse. They are very light, and in this respect unlike many of the bones washed out of the Forest-Bed and found on the shore, which are generally heavy, being infiltrated with oxide of iron. Further on the peat lay upon blue clay, penetrated with roots exactly like the submarine forest on

* Proc. of Geo. Soc. of Liverpool. Session 1871.

the shore, the peat being very hard, and 3 feet 9 inches thick. From midway between manholes Nos. 3 and 4, the pipes were laid on a thin stratum of the peat, forming the bottom of the peat, at about 10 feet above Ordnance Datum. From this point to manhole No. 7, west side of the railway, the bottom of the peat was nearly a dead level, lying upon stiff blue clay. At this point my description must stop until the remainder of the trench is excavated.

Along the whole length the overlying stratum is blown sand, averaging about 12 feet deep. As far as manhole No. 4 the peat was very hard and compressed, and contained a good deal of bark and branches, especially towards the bottom, so that it could not be dug with the spade, but had to be "picked." At manhole No. 5 there were about two grafts deep of soft peat, and from thence to the railway the whole of the peat began to be soft enough to be cut by a spade. Instead of roots of trees, we here had the bottom clay intermixed with the leaves of the common flag, the level being about 11 feet above Ordnance Datum. Higher up in the peat, instead of it consisting of water plants entirely, a more varied growth seems to have taken place; such, in fact, as we see in most mosses. Pieces of birch bark and stems of heath were included in it.

There is no doubt that the peat from C to D is the exact equivalent of the superior Peat and Forest-Bed, and that though no marine shells were met with in the underlying formation it represents the Formby and Leasowe Marine Beds. This portion is a little higher than the general level, being a sort of bank, as the Section shows. It will be observed, however, that when the lowest level is reached, the base of the peat is almost on a dead level, and rests on stiff blue clay. A 21 feet tide will rise six

feet above this level, so that when the drainage system of the country was in its natural state it would either be overflowed, or there would be a fresh-water "mere," "shallow," or "broad," there. This, from the remains of "*iris*" mixed with the under clay, apparently is what at first obtained, but gradually it has become grown up with water plants and converted into "moss land."

In a paper contributed to the London Geological Society, I attempted to prove by measurements and observations of my own, that the whole of the blown sand on this south-west coast of Lancashire has taken not less than 2,500 years to accumulate.*

The present section is a striking confirmation of the continuity and extreme slowness with which the sand has travelled inland. From the River Alt to a distance inland of about 1,000 feet the peat is very hard and compressed, so much so, that it could not be excavated without the pick; from thence the surface begins to get soft, until the whole mass at last can be cut with the spade. The natural inference is, first, that the woody matter helps to make the harder peat; and, secondly, that the nearer it lies to the shore, the longer it has been compressed by the overlying weight of sand. It is, also, possible that there may at one time have been a range of high sandhills over it on this length. But not only is the peat less hard the more inland we get, but after making all due allowance for compression it is actually thicker. It has, in fact, been growing for a longer period, but it has been growing conterminously with the travel of sand inland, otherwise we should find sand and tongues of peat in it, or tongues of sand splitting up the peat.

* On the date of the last change of level in Lancashire. Quar, Jour. of the Geo. Soc.

It is very difficult to make minute examinations in a trench; but the Peat and Forest-Bed on the shore has, in places, six inches of vegetable mould under it. The peat by the railway, in one section, has no vegetable mould under it where I have examined it. Further excavations may tell us more on the subject, but the meres and moss lands appear to have originated in the subsidence of the coast, and the banking up of the inland waters by blown sand;* whereas the base of the peat beds where the trees occur, bears indubitable evidence of having been first high and dry forest land.

As the engineering work has been carried out from my plans, and under my superintendence, I can vouch for the accuracy of all the facts stated.

December 13th, 1881.—Since last meeting the excavations have been carried across the railway and along Sandy Lane, a further distance of 682 feet. A heading was driven under the railway entirely in the peat bed, in which the iron pipes were laid. A strong tarry odour came from the peat at this point. At each manhole I have had the level of the bottom of the peat ascertained. At manhole No. 8, a section was cut showing about 14 inches of the bottom part of the peat, and about 16 inches of underclay. This I sent to Mr. David Robertson, ot Glasgow, who kindly consented to examine it for microzoa. I will give you the results in his own words. He says: "I have divided the clay into two parts, an upper and a lower; and the same with the peat. Both sections of the clay, when dry, are whitish in colour. The undermost eight inches dissolve readily in water, and are composed chiefly of fine mud together with a little fine angular sand, having many plant-like rootlets

* See "Geological Lessons among the Sandhills," by the Author, in "Science Gossip," 1881, p. 198.

running perpendicularly up through the clay : no animal remains were detected.

"The next eight inches, as it approaches the peat is more tenacious with less sand, and more difficult to dissolve; and the rootlets becoming stronger than in the underlying clay, together with long flag-like leaves lying flat on the line of bedding.

"At the junction of the peat and clay the two merge for a few inches into each other, and like the underlying clay, is void of animal remains.

"The first seven inches of peat overlying the clay is full of the remains of the long strap-leaf plant*, as seen in the clay below, and lying flat in the same manner, together with a few grass-like leaves, but mostly near the lower portion of the peat.

"The next seven inches, or top section of the peat, is free of the long strap-leaves, and in their place are fragments of twigs of trees; some of them you will see would measure, before they were compressed, an inch or more in diameter. It appears that the strap-like leaves grew on the surface of the clay, which was penetrated by their roots, and their remains were not seen to rise above the lower section of the peat; while the woody plant remains were confined to the upper portion of the peat."

The main mass of the peat is now becoming very full of the remains of birch. Some of the larger branches or

* These remains have almost always been considered by local observers as the leaves of the common flag. Mr. Robertson thought it possible that they might be not leaves but compressed stems. I therefore submitted specimens to Mr. Carruthers, F.R.S., of the British Museum, who says, "The specimens are fragments of stems, most probably rhizomes, shewing the scars of leaves which have surrounded the stem as in many monocotyledons, and showing also undeveloped buds in the axils of some of the leaves. From the material I am unable to determine what plant the specimens belong to."

trunks on being split shew a magnificent pink colour, which in a few minutes' exposure to the atmosphere quickly fades to brown. It was a long time before I could decide what wood this is, but I have now finally demonstrated from various specimens that it is birch. What rendered it difficult of identification was that the silvery skin of the birch bark is seldom found on the larger pieces, and the smaller branches possessing it are not pink, but of a dark yellow or brown colour on being cut into. The lower part of peat seems made up of iris leaves, and the upper graft too; but there are not many to be seen in the main mass, which is about the colour of tobacco when fresh, and finally becomes on exposure like black cavendish. The peat thickens out gradually to seven feet from the turn in Sandy Lane. A little beyond this point the section of the peat in the trench is as shewn, being several feet deeper on one side of the pipes than the other. It has evidently been got out for burning, along this line we are just conterminous with the edge of the previous excavation.

At the last place we tested the thickness of the peat (north of manhole No. 10), the underclay was bluer and more tenacious, and full of rootlets. The peat also begins to dip a little, as shewn in the Section. Some bones were found on the top graft of peat, west side of the railway, and a great many beyond the turn in Sandy Lane, opposite Mr. Francis Blundell's house. They are mostly of the horse—a small variety. The skull of the horse, which I exhibit, was dug out in my presence, and on comparing it with that of a Welsh pony belonging to Colonel Blundell that happened to be on the road at the time, I found it was two inches shorter, and one inch narrower than that of the Welsh pony. The basal part of the antler of a red deer was found in the blown

sand, twelve inches above the peat. The bones I placed with Mr. Moore to-day, and hope to have his report to-night. Considering that they all came from so small a space, I think we must conclude it constituted a land surface for a great length of time. The only bones that came from the part we consider to be the filled up sand, and which contains cockle and other shells, are the skull of the dog, and the small bones; this material being in the cavities of the peat, which, as previously stated, bore signs of having been cut at a previous period.

As regards the age of the deposits, I have taken every possible precaution to throw away nothing that can throw light on it. On examining a map on parchment of the Little Crosby Demesne, belonging to Colonel Blundell, dated 1702, by one Jos. Hawley, I find that there were fourteen houses at "High Towne;" the ancient cross, which still exists, being in the centre of a sort of triangular road space. None of these old houses exist now, but the new villas shewn on my plan are on the same site.

The cross is now at the side of the road, so I take it that the road has been, to some extent, moved since this survey, and that the filling-up in which the dog remains were found, was subsequent to 1702. The old map shews the roads unconnected, and apparently finishing on to the moss. This moss land has been since enclosed and the various lanes connected across it.

I consider that the animal remains have been originally on what was the edge of the moss, that they have been exposed for a length of time, and evidently covered up by the sand blowing on to the moist surface of the moss. At what period it is difficult to say—but the bones are of the same character as those I have found from time to time on the shore, which have probably been

washed out of a similar bed near the sea. Everything points to the fact that they are very ancient; perhaps before our excavations are finished some further light may be thrown upon the subject. One bone only was found so deep as 18 inches in the peat, they mostly occurred in the surface layers. It is evident the red deer has roamed over the place since the first layer of blown sand has accumulated. Remains of the red deer are also found in the silt or alluvium of the River Alt, overlying the inland moss at Altcar.

NOTES ON THE MAMMALIAN REMAINS FROM HIGHTOWN.

By T. J. Moore, C.M. Z.S.L.

Curator of the Liverpool Museum.

The Bones from the excavations for the Hightown Sewer, left with me by Mr. T. Mellard-Reade for determination, comprise the following :—

Equus (Horse).—*Skull* nearly perfect, *small*, long and narrow; extreme length, 16½ inches; extreme width across the orbits, 7½ inches; length of series of six upper molars, 5¾ inches; width of palate at mid-length, 2 inches.—From "First graft of north-side of F. Blundell's plot."

" " *Left radius and ulna*, 14½ inches long.—From "18 inches deep in peat, beyond F. Blundell's plot."

" " *Metacarpal*, 7½ inches long.—Found "in first graft of peat, opposite Frith's gate."

Equus (Horse).—*Do*. upper half, $4\frac{1}{2}$ inches long.—From "Sandy Lane, top of peat opposite F. Blundell's."

„ „ *Fragments of pelvis*, the largest $2\frac{1}{2}$ by 2 by $\frac{3}{4}$ inches. — "From between peat and sand (September 4, 1882)."

„ „ Portion of shaft of left *femur*, small, least girth $4\frac{5}{8}$ inches.—From "6 (?) inches deep in peat, Nos. 1, 2, 3, beyond F. Blundell's."

„ „ *A spindle (?) shaped shaft of bone*, apparently from the upper portion of *right radius* of small *Equus*. Its girth is ovoid, and greatest at mid-length, where it measures 4 inches; from thence it is flattened to both ends, which are forked, and the whole appearance is strongly suggestive of its having been *shaped and used*, as for the winding of lines for fishing or other purposes. The entire length is 7 inches, and the fork at either end is 2 inches deep; one fork is less perfect than the other, and is $1\frac{3}{4}$ wide at the tips.

Note by T. M. R.—I have found several bones on the shore at the Alt mouth, washed out of the peat bed, of a shape similar to this. One of them in particular is smoothly rounded at the inside edge of the forked portion, while others appear as if they might have been gnawed into the forked shape. One of them has parallel indentations obliquely across it, as if produced by a cutting instrument. Another has had a flake of bone sharply split off, and the mark of a very sharp pcinted instrument with which it must have been done; it might be the effect of the blow of an arrow. There are also curious indents and cuts at the ends of this bone that hardly seem the effect of an animal's teeth.

Sus (Boar).—Right *innominate bone* of pelvis (upper and lower ends wanting); acetabulum 1½ inch diameter. — From "top of peat, Sandy Lane, opposite F. Blundell's."

Cervus (Stag).—Basal half of beam of right *antler*, 8 inches long and 6 inches in circumference, attached to pedicel 2 inches long and 5 inches circumference, with 2 inches of brow and one inch of bezantler, separated by an interval of 3 inches. Of good size, and with well-marked surface, but exceeded in both by antlers from Leasowe. Ferruginous in colour from its sandy bed.—From "North of Frith's gate, in sand, one foot above peat."

,, ,, Right *exoccipital* of base of skull, with par-occipital process attached. *Large:* fully equalling the same parts of the skull of a Wapiti Hind (*Cervus Canadensis*), with which I have compared it in default of a better. The posterior face of the exoccipital measuring 2 inches in vertical diameter, and very nearly 1 inch in transverse diameter. Peaty brown, with surface smooth and shining. Bed not stated.

Bos (Ox).—Three well-worn *molars* in left maxillary bone with malar extending to orbit. *Small.*—"From Sandy Lane, top of peat, opposite F. Blundell's."

,, Part of right *innominate* bone, with acetabulum. *Small.*—From "first graft opposite F. Blundell's."

Bos (Ox).—*Metatarsal; small*, 9¼ inches long; 4 inches least girth.—From "Sandy Lane, top of peat, opposite F. Blundell's."

„ *Metatarsal*, 8¾ inches long, and 3¾ inches least girth.—Found "on sand, opposite F. Blundell's."

„ Right *metatarsal*, very small: immature.—From "first graft, west of railway."

Ovis (Sheep).—Two left *lower jaws*, 6 inches and 5½ inches long respectively.—From "first graft of peat, opposite Frith's gate."

Canis (Dog).—*Skull* 5½ inches long, with jaw and limb bones: *recent*.—From "pot-hole of mixed sand and peat, opposite F. Blundell's."

Human: *Lower jaw*, aged, with two right and two left molars, much worn.—From "Hightown Sewer, 3 feet 6 inches below surface. Bank of the Alt."

„ *Left humerus* 12½ inches long; fair size. Bed not given.

„ *Right radius*, 9½ inches long; fair size. Bed not given.

Note.—The above remains indicate that the Horse, Ox, and Sheep were of small size; and that the Stag was a large and vigorous beast, though larger horns occur at Leasowe.—T. J. M.

THE SUBSIDENCES OF LAND IN THE SALT DISTRICTS OF CHESHIRE, AND THEIR CONNECTION WITH THE MANUFACTURE OF SALT.

By Thomas Ward.

During the last ten years, but more especially since the great land subsidence of December 6, 1880, at Northwich, the attention of the public has been particularly called to the remarkable phenomena occurring so continuously in the immediate neighbourhoods of Northwich and Winsford, the great centres of the Cheshire salt manufacture. It was almost universally understood that these sinkings were caused by the abstraction of the rock salt in the form of brine, for the purpose of being made into white salt. As an enormous amount of property not owned by the salt manufacturers was seriously damaged by these subsidences, without any compensation being made to the owners for the damage caused, these latter endeavoured, in the spring of 1881, to obtain redress by a private Bill in Parliament, the basis of which Bill was a small charge on all salt made from brine. The Bill was not obtained, chiefly because of an ingenious line of defence set up by Mr. De Rance, a geologist connected with the Geological Survey Department. Acting on behalf of the Salt Trade, he endeavoured to prove that the great sinkings in the Winsford district were not caused by brine pumping, but were the result of ordinary geological causes which had been at work for centuries. His theory was that a portion of the rainfall had from all time, certainly since the Glacial Period, made its way down to the beds of rock salt, and dissolved a portion of the salt; then being pressed upon by other fresh water

from a considerable elevation, passed away in the form of brine springs into the brooks and rivers, and eventually into the sea. The continual eating away of the rock salt by the water caused the overlying earth to gradually sink, following the fall of the diminishing rock salt. These sinkings extended to the surface where in the neighbourhood of brooks and rivers they formed lakes and pools of water. The old Cheshire meres are lakes thus formed by the solution of the salt, and the present sinkings are new meres formed by the same geological causes as the old meres. This, shortly, is Mr. De Rance's theory, which he put into the form of a paper and read before the British Association in York a few weeks back.

He accounted for the Northwich sinkings by attributing them to the bad mining of past times, which resulted in the mines falling in, and thus making large pits; or, if in the neighbourhood of a brook or river, extensive lakes or meres.

I propose in this paper to show the real cause of the sinkings, and to examine if the geological theory set up by Mr. De Rance can be substantiated by facts.

The subsidences that are referred to in this paper occur in and around the towns of Northwich and Winsford, the two largest salt manufacturing districts in the world. In both of these towns beds of rock salt exist. Rock salt was first discovered in England in 1670, about a mile or so to the north of Northwich, and from that time to the present it has been mined extensively in the neighbourhood of Northwich. The rock salt at Winsford has been but little mined, and not previously to the present century. In 1781 a bed of rock salt of a purer quality than that discovered in 1670 was found below it, under a bed of indurated marl 30 feet in thickness. Up

till about 1782 all salt mined was obtained from the top rock salt as it is called. Since that period the new mines have all been sunk in the bottom rock salt. No mines were ever worked in the top rock salt at Winsford. By keeping clearly in mind the existence of these two beds of rock salt, the first lying from 40 to 65 yards from the surface and being on the average 24 yards thick; the second lying from 75 to 95 yards from the surface and being about 35 yards thick, we shall be able to understand the Cheshire subsidences. All the subsidence, as a rule, is closely connected with the first bed of rock salt. The exceptions to this are very few in number, and will be pointed out. The subsidences are of two distinct characters—either gradual and continuous, or sudden and of short duration. The cause of subsidence is in all cases the removal of the support of the earths above the salt, and the consequent sinking of these earths. This support of the overlying earths is rock salt, so we may say the removal of rock salt is the cause of the subsidence.

We have now to enquire how this rock salt is removed. If we can answer this, we of course determine the true cause of the subsidences. In the case of mining rock salt there is no difficulty whatever in fixing upon the agent; but as most extensive sinkings occur where no salt has been or is being mined, and subsidence does not follow as a necessary consequence of rock salt mining but rather as an accident, it is evident that there is a cause beyond ordinary mining. Now, there is an almost universal agreement that water is the agent that mines or carries away the rock salt, the removal of which leads to the sinking of the ground. We may say that water is the origin in almost every case. The only exceptions to this are two or three mines which fell in, owing to

the roof not being well supported by the pillars of salt left by the miners. I say, advisedly, two or three mines; for, although probably 30 or 40 old mines have fallen in, yet in almost every case the destruction of the mine has been caused by the inbursting of water. Having reached this point, it will be necessary to explain how and to what extent rock salt is affected by water. Whenever fresh water reaches a bed of salt it immediately commences to dissolve the salt, and continues its action until the water becomes saturated. Every 100 parts of fresh water take up about 33 parts of salt by the time saturation point is reached. This means, that the saturated liquor contains, roughly, one part salt to three parts water; or more accurately, about 27 per cent. of salt. Once saturated, the action of the water ceases, and, however great the body of salt in contact with the saturated water, no more waste occurs. Fully-saturated brine stands in relation to water as 1·2 to 1, as far as specific gravity is concerned. Fresh water does not diffuse at all rapidly in this saturated liquor or brine when no motion takes place, as is well known in the salt districts, where it is often customary after heavy rain to run off the fresh water from the surface of the brine reservoir. If, however, the water instead of standing upon the rock salt bed is in motion, it becomes saturated as it travels, taking up salt until it can take no more, when it passes over the surface of the salt and causes no further waste. If as fast as one particle of water passes, it is succeeded by another, a constant wasting action occurs upon the surface of the salt bed.

It will now be seen that to produce a constant waste of the surface of the rock salt, and a constant sinking of the overlying earths, causing subsidence, we must have a continuous supply of fresh water moving on and

carrying away with it particles of salt in solution. What gives the motion to the water? A correct answer to this will show us the true cause of the subsidence. Does the water run down a slope? and is it, therefore, gravity that causes the motion; the water proceeding to some lower point? This cannot be, for the beds of rock salt lie below the sea level, and there is no escape for the water anywhere below; it must escape at the surface of the ground, if at all. There are now two means of causing the water, when saturated, to appear at the surface of the ground. The one is natural, the other artificial. The natural cause is the pressure of a column of water considerably longer from the surface of the rock salt, than the column from the surface of the salt to the point of escape. It is a case of hydrostatic pressure. The longer leg of the inverted syphon contains the fresh water, which forces up the saturated water in the shorter leg, and causes it to flow away. This is the natural method of causing the escape of brine, and the consequent subsidence. The other method is the lifting of the saturated water by buckets or pumps, artificially. One or other of these methods, either the natural or the artificial, is causing the subsidence. Which is it? To answer this question we must appeal to facts. Wherever the escape of brine takes place, it will be seen by its effects. Now scarcely any springs have been so carefully noted as salt springs. Salt is a necessary of life, and men will go to great pains and expense to procure it; hence the existence of a salt spring, even of the very weakest kind, is immediately made known, and it is utilised. I am not aware of the discovery of any brine springs running to waste, in recent times, in any old inhabited country. Indeed, after a thorough examination of a large amount of

evidence respecting salt springs rising to-day and escaping into streams, I say decisively, that there is scarcely a known instance of a fully saturated salt spring running to waste. The great majority are very weak, and do not run at all copiously. I refer merely now to natural brine springs, not to springs produced artificially by borings carried down to the salt beds. Throughout the world then, there are few instances of the natural hydrostatic process above described. I may say that I have not met with a single instance recorded, of subsidence similar to that occurring in Cheshire, resulting from a natural escape of brine. However, Cheshire may be an instance, so it will be well to examine the facts as told in history.

Whittaker ("History of Manchester," vol. ii. p. 115) says:—"The Romans discovered the Salt Springs of Cheshire, and opened the requisite wells to them. These were the present pits of Northwich. The spring at Condate or Kinderton (near Middlewich), lies 16 or 17 yards below the surface." In Domesday Book we have no distinct mention of springs. However, referring to Nantwich, we read—"In King Edward's time there was a Wich in Warmundestron hundred, in which there was a well for making salt." It is very clear, that with the exception of Nantwich, Middlewich and Northwich, all mentioned, no other salt springs or wells were known. In Holland's edition of Camden, 1610, there is no mention of any springs except those of the three "Wiches,"—Nantwich, Middlewich, and Northwich. In King's "Vale Royal," 1656, the evidence is exactly the same. We read—"This shire excelleth (not only all other shires in England, but also) all other countries beyond the seas. For in no countrey where I have been have they any more than one well in a countrey, whereas in

this countrey are four, and all within ten miles together; that is, one at Nantwich, another at Northwich, and two at Middlewich," p. 19. Towards the end of the 17th century there are several papers in the "Philosopical Transactions" referring to the Salt Springs of Cheshire. The only direct mention of springs escaping and running to waste is by Dr. Jackson, 1668, referring to Nantwich. He says: "In two places within our township the springs break up so in the meadows as to fret away not only the grass but part of the earth, which lies like a breach, at least half a foot or more lower than the turf of the meadow, and hath a salt liquour ousing as it were out of the mud, but very gently." These springs still "ouse out of the mud, but very gently," and are not fully saturated. In 1755, Dr. Brownrigg speaks of the Cheshire springs at Northwich, Middlewich, and Nantwich. He does not speak of any escaping, but says that the brine is found above and beneath (this is a mistake) the "mines of fossil salt." "When the salt is in a good measure exhausted, and the brine is so weak that it can no longer be wrought to profit, they then sink pits in other likely places." In 1769, we meet with exactly similar evidence in a description of England and Wales, p. 2. "This county also abounds with salt springs . . . These rise in Northwich, Middlewich, Namptwich, and likewise at Dunham." The Dunham spring is very weak and unimportant.

The whole of this evidence refers to a time when very little white salt was manufactured, and when consequently there would be a free natural escape of brine, if there were any escape sufficient to cause subsidence. The most curious thing is, that in all these books there is not one mention of subsidence caused by salt springs, or indeed of any subsidence at all, except of such a

paltry character as scarcely worth consideration. Even in 1808, when Holland published by far the best work treating on Cheshire Salt, I mean a "General View of the Agriculture of Cheshire," there is no reference whatever to any sinking of land, though we know that there were rock pits fallen in, and the present subsidence had commenced, yet the whole was so slight as to be deemed unworthy of note in a book that recorded every known brine spring and rock salt deposit in Cheshire. The only brine spring mentioned as rising to the surface is one at Middlewich, although the depth from the surface of the springs in all the known salt districts is given. To sum up the evidence from history, it may be said, that no copious escape of brine by natural springs has ever been known or recorded. All the springs rising near to the surface, or flowing over, have been in the district of the three Wiches; and not one outflow of brine has ever occurred at any distance below Northwich. Mr. De Rance, of the Geological Survey Department, has put forward the natural hydrostatic pressure theory, and makes the escape take place somewhere between Frodsham and Northwich. History never records any springs near the spot he points out. It is true in cutting locks some weak brine springs were met with, but none copious, and none escaping prior to the making of the cutting. One fact seems to me to be conclusive of the whole matter. Had there ever been in historic times any such copious escape of brine as Mr. De Rance's theory requires to account for the waste, it must have been found out, and a "*Wich*" or salt town founded. I have stated the evidence prior to the present century, for since 1808, when Holland wrote, the brine in both Northwich and Winsford districts, the only two where subsidence occurs, has never been within many yards of

the surface, and not even so high as the supposed place of escape named by Mr. De Rance, so could not naturally escape; and yet it is during this very period that fully 99 per cent. of the subsidence has occurred. Mr. De Rance's theory was attempted to be supported by the following historical facts. The Cheshire meres are subsidences caused by the solution of the salt underlying them, and its escape into rivers by springs. In 1533 there was a subsidence near Combermere. In 1659 there was another subsidence at Bickley. In 1713 there was a subsidence at Weever Hall. During the present century there have been enormous subsidences, which are still going on. The conclusion intended to be drawn is—the meres were caused naturally, for there was no brine pumping then: the subsidences of 1533, 1659, 1713, were caused naturally, because they occurred outside the salt-making districts. Therefore, the present great sinkings in Winsford district are caused naturally. We do not know that the meres were caused by the solution of salt. This is a mere theory; probable it is true, but certainly not proved. The three subsidences mentioned were of such a minor character that there are no traces of them now, and it is quite possible for all of them to have been directly caused by brine abstraction for manufacture. But granting that they were the result of natural causes, to be consistent we require something more than three small subsidences, which are more than equalled in one week in recent times, during a space of about 300 years. The matter stands thus: In the last ten years subsidences more than a hundred times the extent of those produced during three centuries have occurred,—is the cause the same? It is a long time from the formation of the meres till the present time, and we know Nature works slowly and continuously

from age to age, yet during all that long period of time three tiny subsidences only can be proved. During the last fifty years, at least 200 acres of land have become lakes. If Nature works regularly, where are the 1,200 acres that ought to have formed lakes since 1533? I am forced to confess that after a most full and careful examination, I fail to find any evidence to support the ingenious theory of Mr. De Rance.

If, then, there is nothing, or next to nothing, to support the idea that hydrostatic pressure is the cause of the forcing of the saturated brine from below sea level to the surface, is there any other cause at work doing this? I reply at once, yes; and a cause ample enough to account for all the subsidence going on now, and that has gone on during the present century. I refer to the raising of brine by means of pumps to the extent of at least 4,000,000 gallons per day.

A short *resumé* of what is known of the modern subsidences may help us to determine whether they have been naturally or artificially caused. The first sinking of which we have any record, is mentioned in the second Act obtained for making the River Weaver navigable. This was in 1759. A part of a road near to the Witton Brook fell in, "by the undermining of the lands in the said road, for the getting of rock salt." I have a copy of a map of 1757 showing a pit near this spot, which was afterwards called, in 1765, "Marbury Hole." On a map of 1765, another pit near the Witton Brook had "recently fallen in." From this date till the end of the century there are frequent records of "rock pits," as they are called, being destroyed by the influx of water. It was not till near the end of the century that there was any distinct record made of the general subsidence of the land, as distinguished from the pits called "Rock Pit

Holes" that showed where old mines had been destroyed. I am now speaking of the neighbourhood of Northwich. A map of 1797 shows sinking in the immediate vicinity of the Witton Brook, and from that date we have maps showing the gradual extension of the sinking area. Of late years, and to my personal knowledge, the sinking has rapidly extended, and is now extending—much of it —entirely out of the region of rock salt mines. In Winsford the sinking did not commence at so early a date as at Northwich. In 1831, as I have maps to show, the area under water along the river bank was very small indeed; and on two maps compiled and published prior to 1831, there is not the slightest trace of sinking above Winsford, neither in the Bottom Flash nor near Weever Hall, or the Top Flash, as it is called. In 1848 sinking to a slight extent had commenced at Weever Hall and in Clive. Ormerod (Journal Geological Society, vol. iv. p. 271) says: "At Clive, about fifteen years since, a portion of a field sunk down in the course of a night from two to three feet. At Weever Hall a similar sinking has taken place. In the vicinity the land still continues sinking, and the water now covers land which a few years since formed a field. The land continues to sink along the course of the river to near Winsford, forming large pools. Near Stock's Stairs, about half-a-mile above Winsford, the sinking parts branch to the west and to the east of the river, leaving the banks firm. The bridge has not sunk." This is important evidence. In 1848 there were a series of pools along the river to Stock's Stairs; now this is one very large deep pool, and extends almost to Winsford Bridge. In 1848 the Winsford Bridge had not sunk. Since then it has been raised owing to sinking more than 17 feet, and has cost the county since 1858 £3,274 13s. 6d. in

raising and repairing owing to subsidence. The whole of the town in the immediate neighbourhood of the bridge and even to the north, towards the Salt Works, has sunk very rapidly within the last few years. In 1864, according to a survey made for the Trustees of the River Weaver, the two Winsford Flashes covered about 20 acres; in 1880 they covered 98 acres, and were increasing rapidly. Within the last ten years there have been most extensive sinkings between Marton and Newbridge; also within the same period in the neighbourhood of Northwich very extensive sinkings have occurred, and during the present year I have been eye-witness to more than two acres of land being covered in one small district, and damage to property of more than £2,000 caused. To sum up the facts of subsidence, we may say that the first great sinkings occurred from the middle of the 18th century to the end, and were caused by the falling in of old mines, owing to the breaking in of water. About the end of the last century the first trace of sinking unconnected with mines is noted; about 1830 sinkings at Northwich and Winsford began to shew themselves, and to extend rapidly. Since 1870 the sinkings have been most numerous, most extensive, and most formidable in their character.

It is evident, then, that since the commencement of the present century some cause has been at work more powerful than at any previous historic period, and that this cause must have increased in intensity since 1830, and most rapidly so since 1870, as shewn by the increase in the effects produced. Can we find a cause which previous to the present century was small, though operating, and which has increased during the present century, and most markedly so as the years have progressed—increasing most largely within the last ten years?

The great factor in the "Natural Cause" of Mr. De Rance is the rainfall. According to Mr. Baldwin Latham, C.E., the exact amount of brine escape can be measured by the rainfall. Now has there been an increase in the amount of rainfall during the present century, and has this amount continued steadily to increase as the years have rolled on, till during the last ten years it has been enormously in excess of any previously known period? It is well known that such has not been the case. The rainfall has not increased. Glaisher's tables show a decrease. If, then, we have a constant factor but an increasing product, and a product which continues to increase with ever greater rapidity, there is no other conclusion to come to but that the constant factor (the rainfall) cannot possibly be the cause of the rapidly increasing product.

If, then, we cannot explain the results by natural means, let us examine the artificial factor at work and see the result. The amount of white salt sent down the River Weaver is a fair representation of the amount of salt extracted by pumping up the saturated brine, and consequently a fair measure of the support of the overlying earths carried away by water annually. Prior to railways it was a more accurate measure than now. To get it more closely of late years, it will be necessary to add one-third to one-half more to it. I now produce a table carefully compiled from official statistics, showing the shipments of white salt down the Weaver.

WHITE SALT SHIPPED DOWN THE WEAVER :—

1732	... ...	5,202 tons.
1744	... ...	8,279 ,,
1764	... ...	18,637 ,,
1777	... ...	31,000 ,,
1796	... ...	100,155 ,,

1801	... ...	142,675 tons.
1810	... ...	170,757 „
1820	... ...	186,666 „
1830	... ...	312,012 „
1841	... ...	414,156 „
1850	... ...	607,395 „
1860	... ...	695,772 „
1870	... ...	901,158 „
1880	... ...	1,087,214 „

It is admitted on all hands that the make of salt in 1880 from brine was at least 1,600,000 tons. Let us now examine the table: Early in the 18th century very little salt was made, and no record of sinking. In the middle of the century very little salt still made, no record of sinking. At the end of the century a considerable increase took place chiefly from Northwich. Holland, in his "Agriculture of Cheshire" says on p. 321: "The annual average of the last ten years (1796 to 1806) of salt sent down the Weaver is from Winsford, 44,384 tons, and from Northwich, 84,933 tons, giving a total average of 129,317 tons." At this period the first clearly mapped out subsidences occurred at Northwich; none are yet recorded at Winsford. In 1830 we have an enormous increase. The fact is that in 1825 the heavy duty on salt was taken off and the trade increased rapidly. Subsidences now are recorded in the neighbourhood of Winsford, and the Witton Brook at Northwich, as maps show, was much increased. In 1850 we find another enormous increase: the East Indian trade was opened to English salt. The town of Northwich began to sink more rapidly and the outskirts were seriously affected, whilst the top of the brook continued still to increase and deepen. At Winsford the pools along the Weaver increased, and the sinking advanced to the town. In 1870

there was again an enormous increase: the Chemical or Alkali trade had sprung up and grown very rapidly, as the following statistics show: In 1862 there were used 254,000 tons of salt in making alkali. In 1874 this reached 500,000 tons. From 1870 onward the quantity of salt manufactured kept on increasing, and during the ten years from 1870 to 1880 there were no less than 9,619,232 tons of white salt sent down the Weaver. Add to this fully 3,000,000 of tons by other means of communication, and we have considerably over 12,000,000 of tons of salt removed by the water pumped up for salt making during ten years. During this ten years the subsidences have been very extensive, rapidly increasing, and destructive in their effects.

Here we have a rapidly increasing factor and a rapidly increasing product. In the direct ratio of the increase of the factor is the increase of the product.

The problem we started with was this: Here is a product small at the beginning of the century, increasing rapidly and continuously, but more markedly so at certain times and periods. Again for the formation of this product we have but two possible factors—a natural one and an artificial one. The natural one is a *constant*, or so nearly so as to be treated as such; the artificial one is a constantly and continuously increasing one, and one marked by more rapid increases at certain times and periods. Which factor must cause or create the product? There can logically be but one reply—the artificial one.

The only evidence we have of the solution of rock salt by water naturally is in connection with the great salt mountain of Cardona in Spain, which is entirely exposed to the weather. Karsten, in referring to the waste, says that it goes on at the rate of four inches in a century. This is very slow and not in any way comparable

to the waste of underground rock salt in Cheshire not exposed to the weather. Is it probable that natural causes—by this is meant rainfall—would more seriously affect the bed of salt covered by upwards of 100 feet of clay, and only approachable at a very limited portion of its area, than the mountain of rock salt entirely exposed to all the rain that fell? Again in Kohat, in N.W. India, the rock salt lies exposed to the weather on hilly ground, and the utmost waste noted has been about two feet in a century. Looked at in whatever way we may, we cannot but conclude that natural causes are not producing the great subsidences in the salt districts of Cheshire. I do not deny that salt springs when running away into rivers cause a certain amount of waste. They must do, but their action is so slow as only to be perceptible in geologic ages, and they may be dismissed as a factor producing changes perceptible in a generation.

I have not said anything about the subsidences caused by mines sinking in the neighbourhood of Northwich, for the area occupied by sunken mines is only a small portion of the district suffering from subsidence, and there cannot be the smallest doubt but that brine pumping is the cause there as at Winsford.

The great changes in Cheshire are like many other: not the result of Nature as in all the early geologic ages, but of one of the latest factors concerned in the changes wrought upon the earth's surface—I mean Man.

THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF FLINTSHIRE.

By G. H. Morton, F.G.S.

Contents.—1. Introduction. 2. Typical section of the Carboniferous Limestone and Cefn-y-Fedw Sandstone of the west of Mold. 3. The Country to the south of Mold. 4. The Country to the north of Mold. 5. Outliers of Carboniferous Limestone along the east of the Vale of Clwyd. 6. Lists of the Fossils found in the Carboniferous Limestone and Cefn-y-Fedw Sandstone of Flintshire. 7. Conclusion.

INTRODUCTION.

The Carboniferous Limestone and Cefn-y-Fedw Sandstone are fully developed in Flintshire, and extend continuously along its south-west border, from near Llandegla to Prestatyn, a distance of about 22 miles. The south-west margin of the county is very irregular, so that some portion of the Limestone, at its southern extremity, extends into Denbighshire. At Tremeirchion, Bodferi, and Caergwrle, there are outliers of the Limestone, besides others along the east of the Vale of Clwyd. The country where the Carboniferous Limestone, Cefn-y-Fedw Sandstone, and Coal-measures occur, is shown on the maps of the Geological Survey, Quarter Sheets, 79, N. W., N. E., S. W. and S. E. The Limestone invariably reposes on the Wenlock Shale along its western outcrop, and it dips under the Cefn-y-Fedw Sandstone towards the east, which is immediately below the Coal-measures. The Carboniferous Limestone and overlying strata are well exposed near Prestatyn, Holywell, Mold, Llanarmon, Llandegla and Caergwrle, all places of very easy access. There is a succession of fine exposures of the Limestone between Mold and Llanarmon where the thickness has been measured.

Flintshire has received little attention from geologists. In 1857, M. L. Moissenit wrote a pamphlet on the lead mines; in 1870, Mr. D. C. Davies, F.G.S., very briefly described the Carboniferous Limestone and Millstone Grit near Mold*; and in 1876, Mr. J. J. Williams, "The Mineral Resources of Flintshire and Denbighshire."† These and a few short papers by myself are all that have been written on the strata below the Coal-measures of Flintshire. The 1-inch maps of the Geological Survey, already referred to, show the area occupied by the Limestone and overlying strata, but owing to the small scale are of little use when required for any precise details.

Mr. Aubrey Strahan, B.A., F.G.S., has been recently engaged in surveying the northern part of the county on the 6-inch maps for the Geological Survey, and I had the pleasure of going over much of the ground with him, so that when the maps are published there will be a close agreement between them and my description, for some important sections we measured together. Although he has not attempted to represent the subdivisions on the maps as I have described them, he has distinguished by different colours the Cherty Sandstone; the Lower Cefn-y-Fedw Sandstone; the Aberdo Limestone of the north, and the sandstone interstratified with the Arenaceous Limestone of the south of the county; the Carboniferous Limestone proper; and a lower subdivision corresponding to the "Lower Brown Limestone" already described by me. Mr. Strahan has ascertained the position and exact direction of the

*"The Carboniferous Limestone and Cefn-y-Fedw Sandstone between Llanymynech and Minera," gives list of works relating to North Wales.

†"Trans. N. of England Mining and Mechanical Engineering," Vol. xxv. p. 81.

numerous faults and mineral veins, which will render the maps very valuable to the mining community. For above thirty years I have frequently examined various parts of Flintshire, and the fossils in the lists appended have been collected at various times during that period.

The highest part of Flintshire is Moel Fammau, 1819 * feet above Ordnance Datum. The following elevations will give an idea of the relative heights of other places referred to :—

"Crown Inn," Llandegla	852·3	Bryn-gwyn	1113·8
Bed of River, Llandegla	798·0	First milestone on Mold & Ruthin road...............	570·0
Moel Garegog, Llandegla	1354·4	Town Hall, Mold	370·5
Llanarmon	802·4	Moel-y-Gaer	993·5
"Rose & Crown," Graianrhyd......	966·0	Moel Ffagnallt ...	944·7
Quarry just south of Graianrhyd...	949·5	Pen-y-ball	839·6
Llyn Cyfynwy	1250·0	High Street, Holywell	358·0
Llanferres...........	739·0	St. Wenefred's Well	245·0
Belgrave Mine Hill	1324·0	Axton Hill, Llanasa	757·0
Moel Findeg	1196·6	Gop, Newmarket...	819·7
Weir at "The Loggerheads"	607·5	Gwannysgeor	574·0
"Rainbow," Gwern-y-mynydd	785·3	Moel Hiraddug ...	
		Diserth	
		Nannerch	527·8

In my paper on "The Carboniferous Limestone and Cefn-y-Fedw Sandstone of the Country between Llanymynech and Minera, North Wales," I gave a general

* Cr. 1818·6. Sur. 1818·9. B.M. 1820·5.

section of the Carboniferous strata below the Coal-measures, and described how the subdivisions of the Carboniferous Limestone continue with remarkable uniformity, while those of the Cefn-y-Fedw Sandstone gradually change in lithological character. In Flintshire there is a gradual change in the subdivisions of both formations, but the Cefn-y-Fedw Sandstone presents a very different appearance when compared with the typical strata on the Eglwyseg ridge at Llangollen. In the Carboniferous Limestone the principal difference is the absence of any thick beds of shale in Flintshire, and consequently of any well-marked line of division between the "Upper and Lower White Limestone," which become united in one subdivision described as the Middle White Limestone, though it is often of a dark grey colour in the north of the county, particularly near Prestatyn, where it is well exposed.

The Cefn-y-Fedw Sandstone changes its lithological character so completely that the Cherty Shale of the south, becomes the Cherty Sandstone of the north of Mold, while the Lower Sandstone thins out altogether at Moel-y-Gaer about five miles to the north of that town. The sandstone interstratified with the Arenaceous Limestone in thick and conspicuous beds to the west of Mold also thins out at Moel-y-Gaer and Moel Ffagnallt, but the limestone continues northward as the Upper Black Limestone in the neighbourhood of Holywell and Prestatyn, where the original name of the subdivision becomes no longer applicable. Near Llangollen the Arenaceous Limestone is composed principally of calcareous sandstone, and was described as the base of the Cefn-y-Fedw Sandstone, but in Flintshire where it becomes interstratified with thick beds of limestone, and finally becomes a limestone subdivision altogether, it has been

considered most convenient to include it with the Carboniferous Limestone. At Gwern-y-mynydd, near Mold, where the beds of sandstone attain their maximum thickness, the Arenaceous Limestone contains great numbers of *Productus giganteus*, and near Pentre Halkin, thousands of this species may be seen in the limestone strata of the subdivision, where the sandstone beds have thinned away. The great number of fossils exposed in the quarries near the latter place is remarkable, and it has long been known for the beautifully preserved Polyzoa that occur there.

The Upper Grey Limestone about Halkin is of a lighter colour than usual further south, and some beds are composed of encrinital marble, while the remarkable zone of tabulate corals, which seems always to form the highest beds, is well exposed. The occurrence of this coral reef, which extends from near Llanymynech to near Prestatyn, indicates a pause in the subsidence of the Carboniferous sea-bottom, over a considerable area, and the luxuriant masses of coral spread out and exposed at frequent intervals is perhaps the most interesting palæontological observation that I have to record.

The country around Newmarket, about two miles from Prestatyn, exhibits numerous sections of the whole of the Carboniferous Limestone. The Lower Brown Limestone occurs on the west of Moel Hiraddug in a quarry at its base, and the Middle White Limestone forms the great mass of the hill. The most fossiliferous locality in the Middle Limestone of North Wales is Axton Hill, close to Newmarket, where there are several small quarries. Nearer the latter village the Upper Grey Limestone occurs and is well exposed in several quarries where the ordinary fossils occur. The Upper Black Limestone is also exposed within a short distance. In this locality there is

little or no drift, and the limestone is frequently to be seen, so that the succession and general lithological character may be observed and the fossils collected. The subdivisions of the Limestone are also well exposed along the end of the ridge above Prestatyn, where they suddenly end, being thrown down by a great east and west fault.

SUBDIVISIONS OF THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF THE SOUTH OF FLINTSHIRE.

	Subdivisions.	Thickness in feet.	Locality where well exposed.
Cefn-y-Fedw Sandstone.	Aqueduct Grit......	50	Pentre - bach and River Terrig.
	Upper Sandstone and Shale.........	100	River Terrig and Moel Garegog.
	Cherty Shale.......	250	Tir - y - coed and Graianrhyd.
	Lower Sandstone and Conglomerate	50	Gwern - y- mynydd and Pen-y-foel.
Carboniferous Limestone.	Arenaceous Limestone	400	Bryn - gwyn and Moel Findeg.
	Upper Grey Limestone	200	Cat Hole Mine and Maes-y-safn.
	Middle White Lime stone	600	Cefn Mawr and Pwll-heli or Belgrave Hill.
	Lower Brown Lime stone	100	Bryn Alyn and Llandegla.
		1,750	

TYPICAL SECTION OF THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF THE WEST OF MOLD.

The Typical Section (Plate 1) shows the contour of the hills and the subdivisions of the Carboniferous Limestone, and Cefn-y-Fedw Sandstone as they occur between Gwern-y-mynydd and "The Loggerheads" on the south of the road from Mold to Ruthin. The north of the road presents a similar section, though the strata are carried a little westward by a fault, along the line of the road, being an upthrow on the north. This section being close to Mold, is so accessible that it has been selected as typical of the succession of the Lower Carboniferous rocks in Flintshire. The absence of drift, and the number of quarries and natural escarpments are so continuous that nearly the whole of the strata is exposed, and can be followed along the strike for several miles both north and south. During the period I gave lectures on Geology at Queen's College, Liverpool, I annually took the students along this interesting section; many members of the British Association in 1870, and the Liverpool Geological Society in 1869, 1876 and 1882.

Mold is situated on the Coal-measures. The hill Bryn-gwyn above Gwern-y-mynydd, where the section begins, is nearly two miles south-west of Mold, being 630 feet above the town and 1,000 feet above the level of the sea. There are no exposures of the strata to the east of Gwern-y mynydd except such as have been obtained from the shafts of mines—particularly at Fron-fawnog—but it was found difficult to correlate them with the beds exposed on the surface.

The Lower Sandstone and Conglomerate is a white sandstone forming the ridge at the top of Bryn-gwyn, and contains bands of white quartz pebbles. The sand-stone is thirty feet in thickness and is indicated

by the letter (*a*) on the section. The strata cropping out to the west of the ridge at a less elevation and exposed in several large quarries belong to the Arenaceous Limestone (*b*) the base being a soft red sandstone. In the valley below, the Upper Grey Limestone (*c*) crops out, and it is well exposed in several places, the upper beds being full of corals which are in a much better state of preservation than on the same horizon at Llangollen.

Further east the ground rises again and forms the hill on which Colomendy Hall stands, composed of the Middle White Limestone, (*d*) though it is not well exposed. On the north side of the road, however, the same limestone forms Cefn Mawr, including the fine cliffs opposite "The Loggerheads," and above the Glan Alyn mine. It is also exposed in the terraced ridges half-a-mile south, near Maes-y-safn. The River Alyn flows along the base of the escarpment of the Middle White Limestone, which occurs in the workings of the Glan Alyn mine to the depth of 210 feet below the river. The base of the limestone occurs about half-a-mile to the west in an old quarry, near Tan-y-Bryn, and in the bed of the stream near Pwll-y-blawd, though it does not seem to resemble the typical Lower Brown Limestone. Still further west the Wenlock Shale appears at the surface, and rapidly rises in the bold masses forming the Moel Fammau range.

The section gives the succession of the subdivisions over the whole of Flintshire, and there are several others running east and west, along which it is quite as clearly shown, though not within such easy reach. The road south of Llandegla, by the "Crown Inn," in the direction of Ruthin, shows the whole of the subdivisions; that from Llanarmon to Graianrhyd is of equal interest, but the former runs by exposures of the Lower Brown Limestone, while the latter is cut through the Cherty

Shale, so that each section exhibits some strata which the other does not. A traverse from Llanferres by Pant-du affords the finest view of the Middle Limestone, as the road, after crossing the Alyn, passes through a gorge, bounded by rugged hills 600 feet high on each side. Similar sections to the east of Rhyd-y-mwyn, Halkin, Holywell, and Prestatyn, prove the same order of succession, varied and modified by numerous faults and the contour of the country. Besides this regular succession of the subdivisions of the Carboniferous Limestone and Cefn-y-Fedw Sandstone along these sections, each subdivision has been traced from one place to another, and when the new Geological Survey maps are published, the strike of each may be followed, and the influence of the numerous faults seen at a glance. The relative position of the subdivisions on the section having been shown, a more minute description of each, as developed in the south of Flintshire, will now be given.

THE COUNTRY TO THE SOUTH OF MOLD.

CEFN-Y-FEDW SANDSTONE.

In Flintshire the relative thickness of the sandstone compared to that of the shale, which constitute the Cefn-y-Fedw Sandstone, is much less than in the typical locality in Denbighshire. Near Llangollen the formation is chiefly represented by sandstone, with a subdivision of shale about the middle, and other beds near the top. In Flintshire the Lower Sandstone and Conglomerate becomes much thinner than in Denbighshire, and finally thins away altogether. The Cherty Shale, however, becomes gradually thicker, harder, and more like flint, while the sandstone at the top of the formation retains much of its original character.

The Cefn-y-Fedw Sandstone of Denbighshire and Flintshire resembles the Millstone Grit and Gower series of the South Wales coalfield. The Sandstone and Conglomerate on the north of that district resemble the Lower Sandstone and Conglomerate near Llangollen, while the Gower series somewhat resembles the Cherty Shale and Sandstone above the Carboniferous Limestone of Flintshire, and the strata in all these places seem to be synchronous. Between Minera and Holywell the gradual thinning away of the Lower Sandstone and the corresponding increase of the overlying shale may be traced; and the sections already referred to across the Carboniferous strata between Llandegla and Holywell prove the gradual alteration described.

The section (Plate 1) along the Mold and Denbigh road does not show much of the Cefn-y-Fedw Sandstone, for only about 30 feet of the Lower Sandstone and Conglomerate is exposed on Bryn-gwyn. It is a hard, light-coloured rock, and in the quarry at the south end exhibits three lines of white quartz pebbles, each about a foot thick, and dips 22° to the east. Excepting Annelid marks, no fossils have been found in it. Below the Lower Sandstone some beds of shale and limestone (25 feet) occur, with the Bryn-gwyn limestone (41 feet) underneath, as shown in the section of the Arenaceous Limestone at page 311, and the inferior beds can all be examined on the western slcpe of the hill.

There are no exposures of the shale above the Lower Sandstone on the east of Bryn-gwyn, but further south the succession can be seen in several places by following the strike of the strata. It is, however, necessary to remember the numerous faults that run N.W. and S.E. which often bring the sandstone beds of the Arenaceous Limestone on the strike of the Cefn-y-Fedw Sandstone,

and it is sometimes difficult to determine the difference, as the former are often conglomeratic. A mile and a-half south at Tir-y-coed the Lower Sandstone is succeeded by a great thickness of Cherty Shale, which can be seen in the plantation. Further south the Lower Sandstone is often very soft, and when this happens the rock does not give any surface indication on the ground; so that the overlying Cherty Shale appears to succeed the Arenaceous Limestone. The soft or sandy condition of the Lower Sandstone may be seen in a large sand pit at Pen-y-foel, a mile from the "Rose and Crown," at Graianrhydd. Similar soft sandy rock occurs at Caergwrle. It is probably from this cause that the Lower Sandstone is not observed along the base of the hills on the east of Llanarmon, or at Moel Gaergog near where it ends against Cyrn-y-brain. Moel Gaergog is a bold rounded hill 1,354·4 ft. high, close to Llandegla; little can be seen of its structure and composition, but here and there a few small openings show that the Cherty Shale is in situ and of the usual white colour. Near the summit there is a talus of large fragments of hard white sandstone, which cover the surface for about 100 feet from the top. They belong to the Upper Sandstone, and as the stones probably descend below the base of the sandstone, it is a question if it exceeds 50 feet in thickness. The Cherty Shale below may be 250 feet thick, but that of the Lower Sandstone is unascertained. No fossils have been observed about Moel Gaergog, but *screwstones*—casts of the stems of encrinites—were found by Mr. D. Mackintosh, F.G.S., at Llyn Cyfynwy.

The Cherty Shale succeeds the Lower Sandstone, and may be seen resting upon it, and the section along the road and brook running east from Graianrhyd

exposes the strata for nearly half-a-mile. It rests upon the Lower Sandstone, 25 feet of which crop out on the road at Bryn-llys, but the fault supposed to throw it up is not visible. Further east after the brook has descended to a lower level, the dip of the shale increases from 10° E. to about 45° N.E.N. and a fault is supposed to bring in the Upper Sandstone. After cropping out for about 75 yards another fault throws up the Cherty Shale, which continues for the same distance with an easterly dip, when the Upper Sandstone is brought in again by a fault, and appears on the strike until it is gradually covered by the drift about 100 yards to the east. The Cherty Shale at Graianrhyd, at the east end of the section, contains *Spirifera bisulcata* and *Streptorhynchus crinistria*, and probably other species if carefully searched for. Both the Lower and Upper Sandstones contain quartz pebbles, and the latter is probably on the same horizon as that described on the summit of Moel Gaergog.

Another section about a mile to the north-east, exposes the strata immediately over those at Graianrhyd, where the succession of the Cefn-y-Fedw Sandstone is continued upwards to the base of the Coal measures. This important section is along the course of the same brook, where it has become wider and is known as the River Terrig, near Tryddyn-fechan, a farm-house a mile and a quarter from the village of Tryddyn. The following is a section of the strata shown in the vertical cliffs, and by ascending the stream half-a-mile nearer Graianrhyd, as the lowest sandstone extends in that direction, and there can be little doubt is the highest sandstone in the Graianrhyd section. In descending, the stream flows through the higher beds exposed in the cliffs until it enters the Coal-measures, a quarter of a mile north-east near Pont

Terrig, and then by Nerquis Hall until it joins the River Alyn. This section of the Tryddyn-fechan beds completes the Cefn-y-Fedw Sandstone in the Tryddyn district.

Upper Cefn-y-Fedw Sandstone	Aqueduct grit and sandstone ...	50	0
	Shale	10	0
	Sandstone	9	0
	Shale	30	0
	Sandstone.	50	0
		149	0

The occurrence of the Aqueduct Grit at the top of the section is very remarkable, for it presents exactly the same lithological character as at the typical locality, near Trevor Station, where the Aqueduct is built on it, and a thick bed of shale forming the base of the Coal-measures rests upon it. It is the upper half only of the 50 feet that is grit, the lower part being an ordinary yellowish sandstone. A conglomerate occurs in places about the bottom of the grit. The 9-feet bed of sandstone varies considerably, sometimes being hard and at other places soft, while the 50-feet bed is hard quartzose fine grained sandstone, with quartz pebbles, and much jointed. The base is not visible, for the dip varies in consequence of undulations of the beds, and the thickness is an approximation of what seems probable there and at Moel Gaergog. The two beds of shale are probably black, but appear to be grey from weathering. The strata dip about 10° north.

There are several quarries near the village of Tryddyn, particularly one close to the Vicarage, where the Upper Cefn-y-Fedw Sandstone is exposed, but they all seem to belong to the 50-feet bed and contain quartz pebbles, the overlying shales and Aqueduct Grit not being exposed.

The Graianrhyd section exposes the lower, and the Tryddyn section the upper strata, of the Cefn-y-Fedw Sandstone, but the thick overlying shale at the base of the Coal-measures is not exposed.

At Pentre-bach, a mile and a-half from Mold, there is another section where the thick shale forming the base of the Coal-measures, and the underlying grit and sandstone are well exposed in a brook-course as follows:—

Coal-measures	Shale with bands of sandstone	40	0
Upper beds of the Cefn-y-Fedw Sandstone.	Hard fine-grained flaggy sandstone..............	12	0
	Grit and conglomerate	3	6
	Hard fine-grained sandstone ...	12	0
		27	6

The strata dip about 8° a little south of east, but it is only the grit and conglomerate that approaches the Aqueduct Grit in lithological character. It is, however, evident that the sandstone is on the horizon of that subdivision, for it is just under the shale which forms the base of the Coal-measures in Flintshire.

ARENACEOUS LIMESTONE.

This subdivision is composed of a series of strata, which vary considerably in lithological character, from limestone to sandstone with or without lime. The sandstone varies in colour and hardness, being frequently of a dull red shade and of a soft sandy character. It is well exposed on Bryn-gwyn, where it crops out from under the Lower Cefn-y-Fedw Sandstone, and the following is a list of the strata as measured with Mr. Strahan:—

ARENACEOUS LIMESTONE, BRYN-GWYN.

	FT.	IN.
Thin shale, limestone, and fine grained calcareous sandstone	25	0
Bryn-gwyn limestone, sandy with quartz pebbles at the top..........................	41	0
Thin bedded limestone.......................	30	0
Calcareous sandstone with lenticular layers of chert	17	0
Limestone and sandstone, some like the Aberdo limestone	17	0
Sandstone	3	0
Cherty limestone	8	0
Limestone with bands of rubble and shale with beds of *Productus giganteus*.........	50	0
Fine grained calcareous sandstone	50	0
Limestone—not well exposed	25	0
Red sandstone	50	0
Limestone	25	0
Soft red sandstone	60	0
	401	0

Although some of the upper beds in this section were measured with a tape, it was found difficult to estimate the thickness of those at the bottom; but 400 feet may be safely accepted as the thickness of the whole of the Arenaceous Limestone at Bryn-gwyn. The usual colour of the limestone is a light brown, and that of the sandstone a light colour about the top and a dull red towards the bottom, where, as already stated, it is very soft and gives a sandy character to the surface. Quartz pebbles are abundant in some of the beds of sandstone, and occasionally occur in the limestone. Both the limestone and sandstone strata vary considerably, and as one rock

changes into the other, sometimes gradually and sometimes suddenly, it is often difficult to decide what to call a particular bed. Although the beds alter so much, both vertically and horizontally, there seems always a thick limestone near the top, variable beds in the middle, and a thick bed of red sandstone at the base of the subdivision.

The lowest bed of soft red sandstone, forming the base of the Arenaceous Limestone at Bryn-gwyn, occurs further south near Maes-y-safn, and a second sandstone crops out in a conspicuous position above it, at the base of Moel Findeg close to an old mine. A north and south fault runs through the hill and throws the strata up on the east, so that the lowest sandstone crops out again by a cottage near the summit. A little higher the second sandstone crops out and presents a prominent scar, visible for a considerable distance, with about 30 feet of limestone overlying it and forming the highest part of the hill, 1,196·6 feet above the sea. Moel Findeg is very conspicuous when seen from the north, and its double peak is shown by the outline on the back-ground of the section (Plate 1). Just south of Moel Findeg the sandstone beds are again exposed in some plantations, where they alternate with limestone as at Bryn-gwyn. In this district there are three sandstones, and they are known to the miners as grits; but it is a question if those in the various mine shafts are on the same horizon. Much of the Galena obtained in this part of Flintshire has been from "flats" as at Fron Fawnog.

Still further south the Arenaceous Limestone occurs at Pant-du, cropping out from under the Cefn-y-Fedw Sandstone of Tir-y-coed. A fault intersects the road just beyond, and throws the strata up on the south, and consequently carries the Arenaceous Limestone to the east. Craig Wolf, near Erryrys, is a conspicuous hillock

composed of sandstone, which is more or less calcareous; and the characteristic red sandstone is well exposed in a road-cutting and several scars. The strike of the Arenaceous Limestone at Craig Wolf is north and south, so that it is continued through the East Bog Mines, where it is again carried east by a fault, and then through Graianrhyd to the west of Llyn Cyfynwy. Between these places the outcrop of the strata is almost continuous, and the sandstone beds form conspicuous ridges in the fields, with precipitous escarpments to the west. The alternate outcrop of sandstone and limestone gives a peculiar aspect to the country; and as the sandstone usually projects above the surface, it is generally easy to find the outcrop of the subdivision. The sandstone when hard has resisted denudation, while the limestone and shale have been denuded, and consequently are much less exposed. Quartz pebbles are of common occurrence in both sandstone and limestone.

The Arenaceous Limestone continues to Llandegla, though it is seldom seen on the surface. At Ty-hir, in the field adjoining the farm, there is a bed of hard sandstone, of which only six feet are exposed, with a few quartz pebbles at the top, succeeded by a light grey limestone fourteen feet in thickness. The beds dip 12° east, and on the road there is a bed of white shale two feet thick containing *Fenestella nodulosa*, with ten feet of limestone and shale resting upon it, all being above the beds by the farm, though there must be some other strata between which are not exposed. At Ffynnon-wen, near Llandegla, on the roadside, there is the following section in a small quarry, where the dip is 12° south-east:

	FT.	IN.
White shale...................................	2	0
Shale and thin limestone	5	0
Limestone in thick beds.......................	25	0
	32	0

It is probable that these beds are at the top of the Arenaceous Limestone, and that the Lower Cefn-y-Fedw Sandstone in its soft sandy condition succeeds on the ascending slope of Moel Gaergog, above the quarry, for the Cherty Shale succeeds higher up, and the hill is crowned by the Upper Sandstone already described.

UPPER GREY LIMESTONE.

The strata of dark grey limestone and shale forming this subdivision occur on both sides of the Mold and Ruthin road, as shewn in the section (Plate 1), and may be traced as they crop out from under the Arenaceous Limestone continuously to Llandegla. The upper beds, with numerous corals, are exposed near the Cat Hole Mine; again in a quarry behind Aberline; along a ridge north-west of Moel Findeg, and at Maes-y-safn close to the "Miners' Arms," where there is a good section at the end of a rounded hill, which extends nearly a mile towards Pant-du. The south end of this hill presents a bold anticlinal section, and with the coral beds on its eastern side, about 200 feet of the Upper Grey Limestone. Further east the bold craggy hill above Bryn Alyn rises to an elevation of 1,324·0 feet, and although the strata cropping out on the western escarpment all belong to the Middle White Limestone, the Upper Grey Limestone overlies it on the eastern side and rests upon it to within 100 yards from the top. The beds dip 10° E., and probably the whole of the strata come in with the slope of the hill, for the Arenaceous Limestone occurs on

the opposite side of the road below. Belgrave Mine is near the top of the hill, and the Upper Grey Limestone ascends up to it. Although this hill is one of the highest and most striking objects in Flintshire, it has no proper name. Pwll-heli was the only one I heard suggested after the small house on its western side, but Belgrave Hill would be a good name for it, the words "Belgrave Mine" on the 6-inch map being the largest and nearest to the summit of the ridge.

The Upper Grey Limestone on the eastern side of Belgrave Hill is very fossiliferous, and I obtained *Productus Margaritaceous* and other species of more common occurrence, including *Aviculo-pecten micropterus*, *Chonetes Hardrensis*, *Productus cora*, *P. giganteus*, *P. semireticulatus*, *Spirifera bisulcata*, *Clissiophyllum turbinatum*, *Lithostrotion irregulare*, *L. junceum* and *Zaphrentis cylindrica*.

When following the strike of the Upper Grey Limestone and other subdivisions along the surface of the ground, it is important to remember that most of the numerous faults run north-west and south-east. These faults are nearly parallel to each other, and they are also mineral veins, as shown on the map of the Geological Survey. Whether they throw the strata up, or down, they always carry the beds to the east, or west, throwing them out of their continuity, though they may usually be found in their altered position presenting the usual lithological character and fossils on both sides of the faults. From Belgrave Hill the Upper Grey Limestone is continued by the village of Erryrys* and the West Bog Mines, where there is a quarry containing numerous fossils. The mine buildings are in ruins (1881), and the stones of which they were built lie in heaps and contain many species. The locality is very prolific in the number

* There is a large erratic block in a field close to the road.

of species: when in company with Mr. Strahan we collected those in the following list in about an hour, and no doubt many others might be obtained during a longer search: *Goniatites sphæricus*; *Bellerophon*; sp. *Murchisonia Verneuiliana; Aviculo-pecten micropterus; Sanguinolites curtus; Solemya Puzosiana; Chonetes Hardrensis; C. papillionacea; Productus cora; P. costatus; P. fimbriatus; P. giganteus; P. latissimus; P. longispinus; P. Margaritaceous; P. semireticulatus; P. Youngianus; Orthis resupinata; Lithostrotion junceum; Fenestella plebeia;* a trilobite and stems of plants like *Calamites* and *Lepidodendron.*

South of the Bog Mines the Upper Grey Limestone is well exposed on the surface in quarries on the road west of Graianrhyd. It may be traced south over the country to the village of Llandegla, where there are quarries and natural exposures, crowded with the most common fossils, *Productus giganteus*, &c., and the corals *Clissiophyllum turbinatum, Lithostrotion irregulare, L. junceum,* and others in abundance indicating the highest beds.

The country between Llanarmon and Llandegla is seldom visited, for there is no railway station nearer than Mold. The wooded limestone terraces on the south-east of Llanarmon are very beautiful, and belong to the Middle White Limestone. After crossing the band of Upper Grey Limestone from the west, the Arenaceous Limestone rises above it, and the Cefn-y-Fedw Sandstone forms hills which rise to the elevation of 1,300 feet. The interesting Llyn Cyfynwy is in a hollow within about 100 feet of the highest ground. It is of a square form; 1,200 yards in circumference, and supplies mines at Minera with water.

MIDDLE WHITE LIMESTONE.

The Middle White Limestone is the most conspicuous portion of the Carboniferous Limestone in Flintshire. It extends in a series of terraced and rounded hills from the great Bala fault at Llandegla, nearly due north, to Prestatyn, a distance of about 22 miles. The scenery along this belt of country is of a very hilly character, especially between Mold and Llanarmon, and the finest view of the most rugged hills may be obtained from Llanferres, about half-way between. The precipitous outcrop of the Middle White Limestone ascends to the elevation of 1,324 feet at Belgrave Hill, and the country along the base of the range is well wooded, and watered by the Alyn, which runs along close to the road. Between Llanarmon and Llandegla there is a succession of rocky ridges of a less elevation, but hidden by lines of plantations, with grassy slopes alternating with them. Prof. W. Boyd Dawkins, F.R.S., has described the caves and contents discovered in the limestone ridges at Berth-y-chwarel, a mile and a-half north; and the neighbourhood abounds with recesses in the rock, where an uncivilized people would find shelter.

The Middle White Limestone is exposed so continuously along the country that the whole of the beds may be examined in many ravines and gorges as well as over the hills. There are also many quarries and mine heaps where fossils may be collected, but unfortunately there are very few to be found, and still fewer that can be obtained in anything like a perfect condition. This general paucity not only refers to individuals, but to species, as the poverty of the list shows. There seems to be little difference between the beds forming the Middle White Limestone, though the colour varies a little on certain horizons and in particular localities.

With regard to the bedding, perhaps the upper beds are on the average thinner and most fossiliferous, while the lower ones are of a more massive character; but there is no divisional line of separation, and no such frequent beds of interstratified shale as in the same subdivision near Llangollen. There is, however, an interesting quarry section at Garth, near Llandegla, just west of the Toll-gate, where two roads meet, which exhibits a mass of broken rock, with 20 feet of shale and 25 feet of limestone over it, in the form of an anticlinal, as shown in the following wood-cut (Fig. 1). It is an isolated section, so that its position in the Limestone series cannot be seen, but it probably belongs to the upper part of the Middle White Limestone. The shale contains a great number of an *Aviculo-pecten*, sp., and the limestone *Productus cora*, and *Syringopora geniculata*.

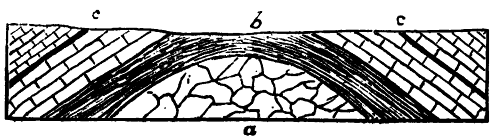


FIG. 1, ANTICLINAL SECTION, GARTH, LLANDEGLA.

a. Limestone, 25 feet. *b.* Shale, 20 feet. *c.* Limestone, 25 feet.

The Middle White Limestone is well exposed in the meadows further north-west, where it crops up in ridges, but not being quarried, no good section can be seen. It also occurs at Berth-y-chwarel, where there is a quarry containing the numerous fossils in the list from that locality.

The thickness of the Middle White Limestone is about 600 feet at "The Loggerheads," and it does not seem to vary, but remains much the same throughout Flintshire. There are several long cross-courses running north and south, as these are faults, and there are no means

of ascertaining the amount of dislocation, it is difficult to arrive at any exact result. For instance, in the typical section (Plate 1), the White Limestone is faulted twice, once at the Cat Hole Mine, and again by the Caleb Bell at "The Loggerheads," but Mr. Strahan does not confirm the latter fault occurring at that particular place.

LOWER BROWN LIMESTONE.

This subdivision occurs in its typical character in an old quarry exactly a mile and a-half south-west from Llandegla, a few hundred yards from two tumuli, which are in the acute angle formed by the junction of two roads. The strata consist of thin bedded black and dark-grey limestone with interstratified partings of black shale, and dip 60° to the east. The beds actually exposed are about 30 feet thick, but there are a few feet of reddish strata a few yards to the west, so that might increase the thickness to 60 feet. There was a hole where the red beds were exposed associated with rotten brown and black shales, and some indifferent specimens of hæmatite were lying about. The limestone probably ends with a fault, which brings up the Wenlock Shale, but the beds exposed are evidently near the base of the Carboniferous Limestone. *Productus comoides* occurs, associated with a few forms that cannot be determined.

At Brynniau, a farm-house half-a-mile to the north, there is a quarry, where the beds exposed are on the same strike and very similar, dipping 55° E.S.E., and contain the following fossils, viz :—*Murchisonia Verneuiliana, Productus comoides, P. cora, Spirifera lineata, Alveolites septosa, Syringopora geniculata* and the remains of plants, just the species that occur in the Lower Brown Limestone at Llangollen. However, 150 yards to the

west of this quarry, at Brynniau, there are two other limestone quarries, at a lower level, which, though nearer to the Wenlock Shale, seem to belong to a higher horizon. The limestone is white, dips 52° E.S.E., and contains fragments of a large *Euomphalus*, *Productus cora* and *Syringopora reticulata*. It seems that these beds must have been let down by a fault, which may be connected with the one supposed to occur near the tumuli, and that there is a boundary fault between the two formations. Limestone is exposed in many quarries to the east of those described; but as it belongs to the Middle White Limestone, the Lower Brown Limestone must be a thin series of beds cropping out along a band of country not more than a quarter of a mile in width.

Nothing is seen of the Lower Brown Limestone again until near Llanarmon, where it may be traced by means of several old limekilns and quarries on the west of the village. There are two quarries by the Methodist chapel, a little further north; and half-a-mile beyond the Alyn, on the main road, it may be again seen with the same strike. Still further north at Llwyn-y-fran, near Bryn Alyn, it forms a steep escarpment facing the river, where it may be easily examined. It differs, however, from the Lower Brown Limestone near Llandegla, for it is a more earthy looking limestone, and more like the subdivision as it occurs further north.

THE BASE OF THE NEW RED SANDSTONE IN THE COUNTRY AROUND LIVERPOOL.

By G. H. Morton, F.G.S.

The Pebble-beds of the Bunter formation form the lowest subdivision of the New Red Sandstone well exposed in the country around Liverpool. "They consist of coarse, hard, brown, or dull red sandstone, divided at irregular intervals by layers of clay and shale, a few inches thick; pebbles and fragments of clay being numerous, but ripple marks very rare."* This description, though strictly correct with regard to the subdivision about Liverpool, does not hold good if applied to a larger area, for the sandstone is sometimes very soft; as in the district between St. Helens Junction and Newton, where it has been mistaken for the Lower Mottled Sandstone. There are other localities where the Pebble-beds present an abnormal appearance, but it is sufficient to mention the sandstone exposed at Bootle, and the cores brought up from the boring in Flaybrick Well, Birkenhead, as strata showing the absence of pebbles. In the latter it was found impossible to draw any line of distinction between the Upper Mottled Sandstone and the underlying Pebble-beds. There is probably a gradual passage from one subdivision to the other, for I do not know of any section showing an abrupt line of junction. Below the Pebble-beds the Lower Mottled Sandstone has been described as of a bright red colour with streaks of white, which often give it a variegated appearance. At the "Blue Bell" Inn, near Prescot and Huyton, it was said to be of a yellow colour.

* Geology of the Country around Liverpool, p. 15, 1863.

Since these descriptions were written, most of the supposed Lower Mottled Sandstone has been proved to be the Upper Mottled Sandstone, as at Toxteth Park and West Kirby; or soft red beds, associated with the Pebble-beds, have been mistaken for it, as at St. Helens Junction. There are several other localities where soft red strata occur, and have been described as Lower Mottled Sandstone, but in most of these there are no means of ascertaining the horizon with certainty, as in the case of the soft red sandstone in the railway cutting under Crown Street and Chatham Street. The strata that seem most likely to be Lower Mottled Sandstone are the yellow beds about Huyton, Tarbock, Rainford and other places, which border the Coal-measures, and seem very like the yellowish beds below the marl in the sand-pit, hereafter described, at St. Helens Junction.

The Geological Survey Maps containing Liverpool and the surrounding country, were published before those sheets representing the country further to the east. In the former, the Lower Mottled Sandstone is shown underlying the Pebble-beds, as at Huyton and Prescot; but in the maps containing Leigh, Bedford, Patricroft and Manchester, there is no such subdivision introduced, for the Pebble-beds always there rest on the Permian. The late Mr. E. W. Binney, F.R.S., constantly maintained that the Lower Mottled Sandstone and the Permian were one and the same. During the last few years some of the difficulties connected with this question have been removed, for not only has much of the Lower Mottled been proved to be Upper Mottled Sandstone, but several shafts and borings have been made, through the New Red Sandstone into the Coal-measures, proving the strata below the Pebble-beds. The sections I am about to describe have mostly appeared before, but in

the "Proceedings" of various societies, which cannot be readily referred to. A recent survey of the district has not added much to previous information, but having waited long in the hope "that something would turn up," I decided to give a *resumé* of all that is known about the base of the New Red Sandstone in the Liverpool area to the present time.

In the early Geological Maps of England and Wales a band of Permian strata was shown bordering the south-west Lancashire coal-field, and although this was eliminated in the later editions, it is again conspicuous on the Geological Survey Maps from Manchester as far as Edge Green, west of Leigh, terminating with a small outlier at St. Helens Junction. There can be no question as to the Permian strata at Bedford; near Leigh, as limestone was long quarried there, and numerous fossils found, including *Tragos Binneyi*.

Permian strata also occur at Bispham, six miles north-east of Ormskirk, where, in a little dell called Skillaw Clough, the following section is exposed, and was first described by Prof. Edward Hull, F.G.S., in the "Memoirs of the Geological Survey," "Geology of the Country around Wigan, 1866:"—

SECTION AT SKILLAW CLOUGH.

Permian	Magnesian limestone	6.0
	Red and purple shale...............	30.0
	Brown and red soft sandstone...	—

A similar section is exposed at Bentley Brook, a mile to the north-east. Unfortunately, no fossils have been found in the limestone at either of these sections; but there seems no doubt that the strata belong to the Permian formation.

In the Memoirs of the Literary and Philosophical

Society of Manchester, vol. xii., 1855, Mr. Binney, in a paper "On the Permian Beds of the north-west of England," described two sections, one at Edge Green, Golborne, and another at St. Helens Junction, 17 and 12 miles from Liverpool, which he gives as follows :—

SECTION AT EDGE GREEN.

"This place is a little to the north of Golborne, and lies near to the North Union Railway. It is about a mile south-south-west of the last described section.* In sinking his shaft, the deep pit called No. 4, for coal, some years since, Mr. Evans met with the following strata :—

		FT.	IN.
	Marl and clay	33	0
Bunter Pebble-beds.	Red sand	4	5
	,, rock	48	0
	White rock	20	6
	Red and white rock spangled	9	0
	White rock	13	0
Permian	Red stone, rather rocky	11	0
	Soft red metal	2	0
	Spangled red and white rock	13	0
	Red metal	2	0
	,, linsey	4	0
	White rock	2	0
	Red stone	11	6
	,, metal	25	6
	,, burr (hard rock)	2	8
	,, metal	26	3
	Brown metal	1	0
	Red rock	82	0
	Coal-measures, of which the variations are given	171	6

* Refers to Eye Bridge.

"The Trias and Permian beds in this section have the same angle of dip, namely 7° east-of-south, at an angle of 14°, whilst the underlying Coal-measures dip 52° east-of-south at an angle of 11°; so that it is evident that the former have a greater inclination than the latter." "The red stone of the 10 feet 6 inches (probably the 11 feet 6 inches bed) no doubt represents the thin beds of limestone parted by clays, and the red burr, 2 feet 8 inches, the lower band of the Bedford section. The same fossils were found in the limestone as at Bedford. The lower new red sandstone although described as red, had beds of a light colour mixed with it."

It does not appear from this description that Mr. Binney saw any limestone himself, but that he obtained the information some years after the pit was sunk; though independently of the occurrence of the limestone and fossils, the strata so much resemble the Permian in other respects that the correctness of his conclusion can scarcely be questioned.

Prof. Hull, in the "Geology of the Country around Wigan," gives an abstract of Mr. Binney's section, as follows:—

EDGE GREEN SECTION.

		FT.	IN.
Drift	Boulder-clay	33	0
Bunter Pebble-beds	Red sandstone with pebbles	95	0
Permian	Red sandstone, marl with bands of limestone, containing Permian fossils	70	C
	Hard burr rock	2	8
	Red and variegated sandstone (Lower Permian)	109	3
Coal-measures			

This section is similar to that given by Mr. Binney, with the addition of the bands of limestone and fossils, about which there may be some doubt; for though they occur in strata to the east, do not occur further to the west.

Recently I visited the shaft, which I found was sunk in 1844, eleven years before Mr. Binney, and twenty-six years before Prof. Hull described it. The colliery manager of the pit, when sunk, is dead, but I happened to find the man in charge of the engine who remembered it being sunk. I found some red metal lying on the bank which he said had recently been brought up from a bad place in the shaft. He had never heard of any limestone or fossils having been found there. As he had resided close by all his life he might have seen the limestone, but would not have been so likely to have heard of the fossils reported to occur there. A wall formed one side of the raised bank and in it I saw blocks of what appeared to be Coal-measure sandstone, another sandstone of a pink shade, probably the Permian, and a hard sandstone, with many pebbles, which had certainly been derived from the Pebble-beds nearer the surface. Of the red metal referred to, there were only a few hundred-weight, which I carefully examined for fossils without finding a trace of any. It would have been impossible to identify the Pebble-beds from the miner's names given to the rock in the upper part of the shaft, though it seems certain that they occur, with a series of sandstones and marls underneath, and a thick sandstone below them resting on the Coal-measures.

Mr. Binney in the same paper described another section near Liverpool, at Sutton, now St. Helens Junction, the description of which I give in full;—

SUTTON SECTION.

"The upper new red-sandstone is seen by the side of the lane leading to the station on the Liverpool and Manchester Railway. It consists of reddish sand without much cohesion. The dip is rather difficult to make out but it seems to be towards the east. Under this sandstone occur 30 feet of red and greenish mottled marls, containing small lenticular markings, and dipping at an angle of 10° to the east-south-east. In these beds Mr. Smith, a gentleman residing in the neighbourhood, and well acquainted with the strata, informed me that he had found nodules of limestone and impressions of shells. Then comes a rock of about 90 feet thick of red and variegated sand used for moulding purposes, and dipping under and in the same direction as the marls last mentioned. Although this sandstone has only been proved 90 feet, Mr. Smith estimates its thickness at above 300 feet. On the top of it are found large nodules, some of them half-a-ton in weight, very hard, and when broken showing a mottled appearance, and containing a good deal of red marl and peroxide of iron. They at first sight might be taken for conglomerates, but to me they are more like chemical aggregations of different substances from a pasty state than rolled pebbles. Whatever their origin, they cannot be distinguished from the bed previously described at the Bedford Colliery, and would appear to prove that the conglomerate at the latter place occurred on the top of the lower new red sandstone."
"The marls and sandstone, both of which I consider to be Permian, rest on upper Coal-measures of a red colour, seen in the dam of the London and Manchester Plate Glass Company."

Professor Hull, in the "Geology of the Country

around Prescot" 1860,* gives the substance of Mr. Binney's paper and states that the blocks referred to "have now disappeared. The purple and mottled marls with Permian fossils (*Schizodus*, *Bakevellia*, and *Turbo*) are not visible in any section, but have been proved in the wells of the brewery to be 30 feet in thickness. They are overlaid by soft, bright red sandstone, forming the base of the Trias exposed to view in a small pit at Pecker's Hill Lane. It is impossible to say how far these beds extend either to the west or east of this spot from the entire absence of sections."

The identification of Permian Marl at St. Helens Junction rests mainly on the evidence of a Mr. Smith, and their occurrence in the wells of the Brewery; and although there are very few exposures of the strata, there is sufficient to confirm Prof. Hull's conclusion. It is probably since the district was surveyed and described, that a sand-pit at the southern extremity of the Permian area has been opened or certainly enlarged in Fisher's yard, Mill Lane, close to Leech Hall.† For many years this pit was considered to represent the Permian Sandstone only, but recently from the action of the weather and the enlargement of the pit, the upper portion has assumed a marly appearance so that the following strata are shown:—

ST. HELENS JUNCTION SECTION.

		FT.	IN.
Boulder-clay or *débris* from it		15	0
Permian	Sandy marl	15	0
	Soft red and yellow sandstone	25	0

* Memoirs Geological Society.

† Possibly one of the two quarries near St. Helens Junction described as Lower Mottled Sandstone, by Professor Hull, 'Geology of Prescot,' p. 14.

The sandy marl dips slightly in an easterly direction, and it is very regularly stratified, while the underlying red and yellow sandstone is false bedded. There is no limestone associated with the marl, and a search for fossils was unsuccessful. The dip is E.S.E., but only a few degrees. The sandy marl is altogether different to any other strata in the neighbourhood, and if it does not actually represent the purple and mottled marl at the Brewery, may be just below or above, for it has the same strike. At the other side of the London and Manchester Railway, in the middle of the triangular area formed by the railways, there is a sandpit where the following small section was exposed in 1881, but was partially covered with water in 1882.

		FT.	IN.
Permian	Red marl with greenish bands	10	0
	Soft red sandstone	3	0
	,, yellow ,, ...	2	0

A few feet of red marl crop out at the corner of a road about 300 yards to the north, but no sandstone can be seen there. The strata in all these sections are on the strike of the marl in the wells of the Brewery, that is as nearly as can be determined over ground so little exposed and so much left to conjecture. The locality has been taken possession of by the Railway Co., embankments thrown across it, and the ground covered with rubbish, so that it is a question if any additional observations on the strata can be made. I remember the supposed Lower Mottled Sandstone west of the Station at St. Helens Junction, but the soft red sandstone with quartz Pebbles in the road cutting beneath the railway belongs to the Pebble-beds, and not to the former as coloured on the Geological Survey Map—even on the recent edition. Although the strata are so little

exposed that no satisfactory conclusion can be drawn, it is certain that there is red shale or marl, with a soft red and yellow sandstone underneath.

During the last seven years several shafts and borings have been made, which help the identification of the strata. All these shafts and bore-holes pass through the Pebble-beds, and, with the exception of one at Bootle, penetrate the Coal-measures, so that the character of the strata has been proved in many places, and we are enabled to form a more satisfactory conclusion as to the base of the New Red Sandstone than formerly.

Just a mile from St. Helens Junction the Bold Hall Colliery Co. sunk two shafts, between 1875-8, and for the following section I was in the first instance indebted to Mr. Henry Bramall, C.E., though I give it in the abreviated form adopted by Mr. A. Strahan, M.A., F.G.S., in an article "On the Discovery of Coal-measures under the New Red Sandstone, and on the so-called Permian rocks of St. Helens, Lancashire."*

SECTION AT BOLD HALL.

		FT.	IN.
	Peat	4	6
Glacial	Clay and sand	63	5
Permian	Red marl and sandy marl†	9	0
	Red mottled sandstone†	21	0
	Red and white metal	30	4
	Red sandstone	57	9
Coal-measures	Red coal-measures	364	9
	Coal-measures	1249	6
	Florida Mine		

* Geological Magazine, Decade ii, Vol. viii, p. 433.

† Lower Mottled Sandstone, according to Mr. Strahan, Geol. Mag. Ibid.

At Ashton's Green Colliery, one mile N.W. from Bold, the most easterly shaft goes through 48 feet of red sandstone, but it was sunk many years ago, so that little is known about it. About a mile N.E. from Bold is Collins Green Colliery, where two shafts pass through the New Red Sandstone into the Coal-measures, and the following is a section of one of them, obtained from Mr. John Mercer, though there is little or no difference between them, for they are only a few yards apart.

SECTION AT COLLINS GREEN.

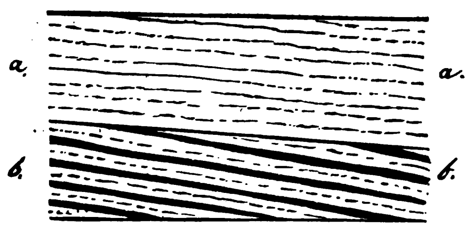
		FT.	IN.
Glacial	Clay	63	7
Bunter Pebble-beds.	Red sandstone	102	2
	Yellow ,,	41	0
	Red rock	37	10
Permian	Red metal	22	4
	Hard dun rock	3	3
	Brown sandstone, with concretions of iron pyrites called "Sulphur Balls"	40	8
Coal-measures	Red coal-measures	151	11
	Coal-measures	1204	10
	Florida Mine		

Another important section was obtained recently at the Lime Pits, near the Newton race-course where the Haydock Colliery Company have sunk three shafts. Fortunately my attention was directed to it by Mr. Bramall, otherwise it might have remained unnoticed by geologists. I considered it so important, that I communicated with Mr. Strahan, and we visited the place together, when Mr. Glover gave the details, of which the following is a condensed section:—

SECTION AT NEWTON RACE COURSE, (LIME PIT, NO. 3).

		FT.	IN.
Glacial	Clay	3	0
	Buck leaf clay	36	0
Bunter Pebble-beds	Red sandstone, with a few pebbles	259	0
Permian	Red shale "soapstone"	9	0
	Hard brown sandstone	7	6
Coal-measures	Red coal-measures	97	9

At the bottom of the shaft we found a considerable space had been excavated and the hard brown sandstone at the base of the New Red Sandstone formed a solid unbroken roof. At the end of a heading from this open space we saw the New Red Sandstone resting unconformably upon the Coal-measures, as shown in the following section:—



a. Strong brown stone. Dips 8° E. *b.* Soft crumbly metal. Dips 10° E.

It shows that the inclination of the strata of both formations is very similar. The unconformity between them was only just visible along about six or eight yards of the strata exposed, and all were of a red colour. The dip of the New Red Sandstone was about 8° E., and that of the Coal-measures about 10° E. I brought up specimens of the beds, and found a large quantity of rock from the shafts exposed on the surface which contained

pebbles and nodules of clay, showing that the 259 feet in the section belonged to the Pebble-beds.

In addition to these sections obtained from shafts, there are several places where the thickness and base of the New Red Sandstone have been proved by borings for water. The details obtained from borings are, however, much less reliable than those from shafts, especially when the strata are so soft that solid cores cannot be brought to the surface. Mr. Strahan in the paper already referred to, gives the records of the strata passed through at the following places, on the authority of Mr. A. Timmins, C.E., of Runcorn, who made the bore-holes, and usually preserves specimens of the beds passed through.

FARNWORTH SECTION.

		FT.	IN.
Bunter Pebble-beds*	Fine-grained yellow and white sandstone	117	0
Permian	Porous sandstone, with millet-seed grains	7	0
	Light-green, red and blue clay	3	0
	Bright-red sandstone.	3	0
Coal-measures	Purple and mottled marl, with bands of limestone	40	0

WINWICK SECTION.

		FT.	IN.
Bunter Pebble-beds	Hard sandstone, with pebbles and thin beds of shale	229	5
Permian*	Red shale	31	7
	Soft sandstone	16	5
	Soft grey sandstone, with concretions of iron pyrites	21	7
	Dull red sandstone with bands of shale	31	0
	Shale	11	0

		FT.	IN.
Coal-measures	Dark red, green and purple marl, with limestone	71	0

PARKSIDE SECTION.

		FT.	IN.
Bunter Pebble-beds	Red, brown and white sandstone with pebbles	150	0
Permian*	Red shale	32	0
	Bright red and yellow sandstone with shale 4 feet, and containing concretions of iron pyrites towards the base.	109	0
Coal-measures	Purple and green mottled marl	5	0

HOLT LANE BRIDGE SECTION.

		FT.	IN.
Permian	Deep red sandstone, crumbling readily, with millet-seed grains	54	0
	Red marl	41	0
	Sandstone	19	0
	Red marl	11	0
	Light red sandstone	35	0
	Red marl	2	0
	Soft light red sandstone with millet-seed grains	33	0
	Soft light red fine sandstone ...	40	0
	Soft coarse red sandstone	96	6

This boring was continued to the depth of 309 feet, but the lower portion could not be obtained.

There is another section much nearer Liverpool, to which final attention must be drawn. In 1878 the

*Lower Mottled Sandstone according to Mr. Strahan—*Geol. Mag.*

Corporation of Liverpool decided to sink an experimental boring at Bootle in search of water, at a considerable depth, in hope of obtaining an additional supply from a source below that of any of the local wells. The firm in Manchester who made the boring, evidently expected to pass through some impermeable beds, and then obtain water from sandstone at a greater depth. There can be little doubt that the Permian marls were expected to occur below the Pebble-beds, and that what Mr. Binney called the Permian, or Lower New Red Sandstone would be found beneath, and that it would yield the anticipated supply of water. This opinion, derived from the succession of the New Red Sandstone in the neighbourhood of Manchester, seemed to admit of no doubt. Geologists, however, most likely to form a correct opinion on the order of the subdivision of the sandstone around Liverpool, stated that the Pebble-beds at Bootle would be only a few hundred feet thick, that the Lower Mottled Sandstone—400 feet—would be found beneath, and that the proposed depth of 1,000 feet would penetrate the Coal-measures. In due course the boring began in the Pebble-beds, and contrary to all expectation, the base of those beds was not reached until the depth of 1,026 feet had been attained. As the boring proceeded, strata of a fine grained character were penetrated, and it was decided to continue to the depth of 1,300 feet. After descending through 274 feet of this sandstone, which was of a very tough character, the operation was suspended without either finding the impervious Permian marl, or reaching the Coal-measures. The fine grained sandstone was found to contain lime, when analysed by Dr. J. Campbell-Brown, F.C.S.;* and if a

* "Analysis of Rocks from the 1,300 feet deep Bore-hole, at Bootle.—"Proc. Liverpool Geol. Soc.," vol. iv., part I, p. 63.

thin bed of limestone, or a thick bed of shale, or marl had been found, there can be little doubt that the strata would have been pronounced Permian. The strata below the Pebble-beds were considered Lower Mottled Sandstone from their position rather than from their lithological character. It was very unfortunate that the boring had to be given up after going to such an unprecedented depth, through strata of an abnormal character. As no beds of shale or marl were met with in the Lower Mottled Sandstone at Bootle, the inference is that they thin out to the west, or occur at a greater depth.

According to Prof. Hull's description of the Lower Mottled Sandstone, it is made up of soft bright red, yellow and mottled sands, fine grained, without pebbles or fragments of other rocks, and no beds of marl are mentioned. But there is no clear section showing the Pebble-beds with the Lower Mottled Sandstone and Permian marl developed below, and it therefore seems most probable that both may represent different conditions of one formation. If the marl thins out towards the west the Lower New Red Sandstone of St. Helens Junction may be the Lower Mottled Sandstone at New Pale and Whitefield Lane, Tarbock; Huyton; Stand House, Croxteth; and Rainford. In the "Geology of the Country around Prescot," Prof. Hull gives a section showing the Lower Mottled Sandstone resting directly on the Coal-measures, without any marl being present. These are the principal localities where this subdivision occurs; they are all isolated exposures, and seem to be near the base of the New Red Sandstone.

My object in bringing this paper before you is to place on record, and bring into a focus, all that is known and worth recording of the base of the New Red Sandstone in the country around Liverpool.

It will be seen from the sections of shafts and borings that the Pebble-beds occur at the surface in every instance, and that the thickness passed through in each case leaves no doubt regarding their occurrence.* With the exception of Bootle, each section presents a series of sandstone and marl of no great thickness, below the Pebble-beds, which much more nearly resemble the Permian of Manchester than the Lower Mottled Sandstone of Liverpool. I have already shewn that the Pebble-beds are frequently represented by a soft red sandstone, without any pebbles, and have frequently been mistaken for the Lower Mottled Sandstone. As this has occurred on the surface where a considerable area was exposed, great caution must be exercised in receiving as proved the sections derived from bore-holes.

In conclusion, it seems to me probable that the Permian Marl, *provisionally so called,* thins out from the east towards the west, and that the Permian of the Manchester district is represented by the Lower Mottled Sandstone of the Liverpool district. The variation in the thickness of the Lower Mottled Sandstone and the Permian is probably in consequence of varying contour of the surface of the Coal-measures.

There may be some confusion between sections of the Upper Coal-measures, which are of a red colour, and the supposed Permian, especially as both seem to contain a bed of limestone, and the section showing unconformity at Newton race-course does not prove much, for it may be only an instance of false bedding.

---

* Except, perhaps, Bold and Farnworth, but both of these places are on the Pebble-beds according to the Geological Survey Map.

NOTE.—Since this Paper was read, an important section has just been obtained from a boring now in progress at Hunt's Cross, Woolton, much nearer Liverpool than St. Helens Junction, for the particulars of which I am indebted to Mr. A. Timmins, C.E., who is conducting the operation. The place is near a doubtful boundary line between the Pebble-beds and the Upper Mottled Sandstone, on the Geological Survey Map. After passing through 137 feet of drift a bed of marl was found, which has been penetrated to the thickness of 200 feet—337 feet from the surface—without reaching the bottom of it. It would be absurd to call this marl Lower Mottled Sandstone, and most likely it is Permian, just below the Pebble-beds, which is the usual succession in the country to the east of the boring. Before the age of this marl is finally decided, it is desirable that fossils should be obtained, if any occur in it; but the stuff comes up the bore-hore in the condition of powdered dust, so that there is little chance of finding any at present. Now that attention has been directed to the importance of finding fossils, it is hoped that they will soon be found in some of the localities where the marl occurs. Meantime it seems probable that the position of the marl is between the Pebble-beds and the Lower Mottled Sandstone, and that all the strata below the former belong to the Permian. It is, however, possible that it may ultimately be proved to be Keuper marl.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D.Sc., Queen's College, Galway.
JOHN W. JUDD, F.R.S. F.G.S., London.

MEMBERS.

ARCHER, F., B.A., Boundary Cottage, Crosby.
  14, Cook Street.
*†BEASLEY, H., 20, Chesnut Grove, Wavertree.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
*BROWN, J. CAMPBELL, D.Sc., F.C.S., 27, Abercromby Square.
COOGAN, P. M., C.E., 28, Green Lawn, Rock Ferry.
DAVIES, C., 8, Kinglake Street, Edge Hill.
DODD, J., 2, Derby Terrace, Rock Ferry.
*†ESKRIGGE, R.A., F.G.S., The Woodlands, New Brighton.
  18, Hackin's Hey.
FITZPATRICK, M., 62, Seel Street.
FITZPATRICK, J. J., 62, Seel Street.
†FOSTER, E., 7, Newstead Road, Smithdown Road.
GREEN, A., York House, Old Chester Road, Rock Ferry.
  9, Canning Place.

GRIFFITHS, J., 4, Exton Park, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B., Hon. Treasurer, Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
HERDMAN, W.A., Prof., D.Sc., F.L.S., F.R.S.E., University College.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W., B.Sc., 21, Verulam St, Upper Parliament St.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport.
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
LEA, T., Vale Cottage, Huyton Quarry.
LEIGH-GREGSON, S., Aigburth Road.
Slater Court, 5, Castle Street.
*MACKINTOSH, D., F.G.S., 32, Whitford Road, Higher Tranmere.
*McCLAY, J .L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MAYER, J., F.S.A., Pennant House, Lower Bebington.
*MOORE, T. J., C.M.Z.S.L., Newsham Drive, Newsham Park.
Liverpool Museum.
*MORGAN, A., 97, Hartington Road, Sefton Park.
57, Seel Street.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I. (Hon. Secretary) 4, Onslow Rd., Elm Park. 122, London Road.
†MOTT, C. G., Sunnyside, Cavendish Road, Birkenhead.
McMILLAN, A., Conway, North Wales.
PATERSON, J., Palmyra Street, Warrington.
PEARSE, W., 21, Harrington Street.
Green Bank Farm, Wavertree.
*†PICTON, Sir J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
PEARSON, J. E., Golborne Park, near Newton-le-Willows.
QUILLIAM, W. H., 30, Rufford Road, Fairfield.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Valley Lodge, Borough Road, Birkenhead,

ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
STONE, R., Jun., Newton Park, Newton-le-Willows.
STRONGITHARM, G., 77, Whetstone Lane, Tranmere.
SPARGO, E., Bangor, North Wales.
SHERLOCK, C., 63, South John Street.
TATE, G., Ph.D., F.G.S., F.C.S., Liverpool College of Chemistry 96A, Duke St.
THOMAS, H., 21, Kinglake Street.
TIMMINS, A., C.E., Mill House, Runcorn.
WILSON, W. H., St. Michael's Hamlet, Aigburth.
31, Wapping.
WRIGHT, B.M., F.R. Hist. Soc., 204, Regent Street, London.
*WARD, T., Northwich, Cheshire.
YOUNG, H., 12, South Castle Street.

ASSOCIATES.

MORGAN, Mrs., 97, Hartington Road, Sefton Park.
MORTON, Miss S. E., 4, Onslow Road, Elm Park.
ROBERTS, Mrs., Kennessee, Maghull, Lancashire.
READE, Mrs., Park Corner, Blundellsands.

---

* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-FOURTH,

1882-3.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART V.—VOL. IV

LIVERPOOL:
C. TINLING & CO., PRINTERS VICTORIA STREET.

1883.

OFFICERS, 1882–3.

President.

DANIEL MACKINTOSH, F.G.S.

Vice-President.

ISAAC ROBERTS, F.G.S., F.R.A.S.

Ex-President.

J. CAMPBELL BROWN, D.Sc., F.C.S.

Honorary Treasurer.

EDWARD W. HANCE, LL.B.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

HENRY YOUNG.
GEORGE TATE, Ph. D., F.G.S., F.C.S.
HENRY C. BEASLEY.
T. MELLARD READE, C.E., F.G.S.
CHARLES RICKETTS, M.D., F.G.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

Advocates' Library, Edinburgh.
Belfast Naturalists' Field Club.
Birkenhead Free Public Library.
Do. Literary and Scientific Society.
British Museum.
Bristol Naturalists' Society.
Bodleian Library, Oxford.
Boston Society of Natural History, U.S.
Chester Society of Natural Science.
Dudley and Midland Geological and Scientific Society.
Epping Forest and County of Essex Naturalists' Field Club.
Editor of "Geological Record."
" "Nature."
" "Geological Magazine."
" "Science Gossip."
Ertborn, Le Baron O. Van, Anvers Belgique.
Geological Society of Edinburgh.
Geological Society of Glasgow.
Geological Survey of India.
Geological Society of London.
Geological Society of Manchester.
Geological Survey of the United States.
Geological and Polytechnic Society of the West Riding of Yorkshire, Leeds.
Geologists' Association, London.
Glasgow Philosophical Society.
Hayden, Dr., United States.
Koninck, L. G. de., Prof., Liege.
Leeds Philosophical and Literary Society.

Liverpool Athenæum.
,, Chemists' Association.
,, Free Public Library.
,, Geological Association.
,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
,, Polytechnic Society.
L'Universite Royal De Norvége, Christiana.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal D'Histoire Naturelle de Belgique.
Museum of Practical Geology, Jermyn Street, London.
North of England Institute of Mining and Mechanical Engineers.
Orleans County Society of Natural Science, Vermont, U.S.
Owens College, Manchester.
Royal Dublin Society,
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
Smithsonian Institution, Washington, U.S.
Société Geologique de Belgique, Liege.
Société Geologique du Nord, Lille.
Toscana Societa di Scienza Naturali.
University Library, Cambridge.
Warwickshire Natural History and Archæological Society, Warwick.
Watford Natural History Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-FOURTH.

OCTOBER 10TH, 1882.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been audited by Mr. HENRY BEASLEY and Mr. ISAAC ROBERTS.

The President then read his Annual Address—

ON THE POST-TERTIARY CHANGES OF LEVEL AROUND THE COAST OF ENGLAND AND WALES.

NOVEMBER 14TH, 1882.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

Professor W. HERDMAN, D.Sc., F.L.S., F.R.S.E., was elected an Ordinary Member.

The following papers were read :—

DESCRIPTION OF A NEW MAP OF STORETON QUARRIES, CHESHIRE.

By G. H. MORTON, F.G.S.

THE DENUDATION OF THE LONGMYNDS, SHROPSHIRE.

By Henry Beasley.

DECEMBER 12th, 1882.

The President, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following communication was read:—

ON CHANGES OF LEVEL CAUSED BY ACCUMULATION AND DENUDATION.

By Charles Ricketts, M.D., F.G.S.

JANUARY 13th, 1883.

The President, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following communications were read:—

THE THEORIES OF THE ORIGIN OF METALLIC VEINS.

By G. Tate, Ph.D., F.G.S., F.C.S.

NOTES ON THE CARBONIFEROUS LIMESTONE OF BELGIUM, MADE DURING A RECENT VISIT TO THAT COUNTRY.

By G. H. Morton, F.G.S.

FEBRUARY 13th, 1883.

The President, DANIEL MACKINTOSH, F.G.S., in the Chair.

The following communication was read:—

A TRAVERSE OF THE YORKSHIRE DRIFT.

By T. Mellard Reade, C.E., F.G.S.

MARCH 13TH, 1883.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S. in the Chair.

Dr. ARCHIBALD GEIKIE, F.R.S., was elected an Honorary Member.

The Rev. JOHN MANSELL was elected an Ordinary Member.

The following communication was then read:—

THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF THE NORTH OF FLINTSHIRE.—PART II.

BY G. H. MORTON, F.G.S.

PRESIDENT'S ADDRESS.

I HAVE selected for this address a subject which may be regarded as both special and general, namely, the *changes in relative levels of land and sea along the west and south coasts of England and Wales.* At the very outset, however, it may be necessary to attempt an answer to the questions—What is a *submerged forest?* and, What is a raised beach?

Submerged Forests.—As it is certain that a great part of the sea-bed surrounding the present coasts of England and Wales was dry land in Post-tertiary times, the deepest parts of what is now the bed of the sea, with forests on their surfaces, must have been first submerged, and the shallowest forest-covered parts the last. But it is probable, if not certain, from what may still be seen at extreme low water, that the more ancient surfaces of forest-growth have in many, if not in most places, been buried under sedimentary deposits, the least obscured surfaces where they have not been washed away by the waves, being those which sank down the latest. These may be called *pre-glacial* or *interglacial* surfaces of forest-growth, and they may be traced under the waters of the Bristol channel, and many other shallow seas. But it is likewise certain that many forests which have grown along sea-coasts in *post-glacial* times have partly or wholly subsided beneath the sea, and it is probable that in many places the process is still going on.

Raised Beaches.—According to Professor James Geikie (with whom I have lately been corresponding on the subject), the only true raised beaches regarded as distinct

from portions of sea-beds, are rock-shelves or terraces which were excavated by the sea in inter-glacial times. The raised beach of Cantyre, with its cliffs and caves is, according to Professor Hull, the most strongly pronounced of all the raised beaches of Scotland. Its inner limit is about thirty feet above the present sea-level. According to Professor James Geikie, the shingle-covered "raised beaches" along the W. coast of Scotland are of post-glacial age, but in the S.W. of England I have no doubt they are inter-glacial. Along the coasts of England and Wales the so-called raised beaches (with a few exceptions, where the conditions were favourable to the formation of terraces) are raised portions of the sea-bed or rather of the tidal zone, so that they are beaches as regards the shingle or sand of which they are composed, but generally not beaches as regards their external form.

Submerged Forests and Raised Beaches along the Coast of Cumberland, Lancashire, and Cheshire.—As it is now a long time since I was familiar with this coast, and as much has been written about it by Liverpool Geologists and the Geological Surveyors, I must be very brief in my remarks. I have a distinct recollection of a terrace near Whitehaven, surmounted by a cliff-line, which suggested the idea of a raised beach; and I have no doubt that many indications of changes of level might be found around the shores of Morecambe Bay. Among them there are two undoubted instances of raised sea-beds, if not, strictly speaking, beaches, one at Rampside (discovered by the late Miss Hodgson), and the other near Fleetwood. I am not aware that any notice has hitherto been taken of the remains of a forest a short distance north of Parkgate, portions of which are alternately exposed and covered up by sand which,

at intervals, is brought up and washed away by tides and waves. It suggests the idea that peat and forest-beds may once have been more extensively distributed than at present. Along some parts of the east shore of the Dee estuary, there is a deposit of sand above the upper Boulder-clay which might be mistaken for a raised beach, supposing the observer to overlook the pieces of coal, bits of broken tobacco-pipes, &c., which it contains imbedded, and which shew that it is merely blown-sand.

Submerged Forests and Raised Beaches along the Coast of Wales.—Along the base of Halkin mountain, on the western side of the estuary of the Dee, the sea has worn back the glacial drift so as to leave a line of cliff which, from about the neighbourhood of Flint, is continued north-westward for a considerable distance. It is not, strictly speaking, a raised beach, because the base of the cliff-line is generally as low as high-tide level. Proceeding still westward, I shall pass over the well-known epitaph in Abergele churchyard, because it does not name the place where the man lived which, according to the epitaph, is now under the sea. The area covered by the Lavan Sands which (according to Professor Haughton) were brought by tidal currents from the south-west coast of Ireland, is said to have subsided in very recent times, if the subsidence is not still going on. There is a tradition that the waves have washed over and destroyed a fruitful vale, along with a palace; and it is said that at very low tide the waves may still be seen breaking over ruined houses and causeways. According to Ramsay there is a raised beach on the shore of Redwharf Bay, on the N.E. coast of Anglesey, and a submerged forest south of Holyhead. There are similar forests on the west coast of Wales, near Aberystwith,

Aberaeron, Cardigan, in St. Bride's Bay; and near Tenby, on the south coast of Wales.

Submerged Towns, &c.—Nearly due west of Moel Tryfan, Caernarvonshire, a submerged town may be seen marked on some maps, and farther south, near Barmouth, there is a kind of causeway, called Sarn Badrig. The five fathom line approaches near to it on both sides. It seems to be the top of a wall which partly or wholly kept the sea out from what was called the "Lowland Hundred." About the year 500 a flood-gate was left open, and the sea overflowed the whole hundred. If this historical account be reliable, it would tend to throw doubt over the tradition of the subsidence of the Lavan Sands (already noticed), by suggesting the possibility of the area they cover having once been artificially protected from the inroads of the waves, which at a later period may have proved triumphant. In connection with this subject it might be worth while to inquire how far the Flemings, about the time when they settled in the peninsula of Gower (South Wales), may have roamed northward along the west coast of Wales, and by the erection of embankments, converted portions of the sea-bed into fertile land with human habitations.

Submerged Forests and Raised Beaches along the shores of the Bristol Channel.—Among the most instructive of these submerged forests is the one at Porlock Bay on the south coast of the channel. The trees of this forest, according to Mr. Godwin-Austen, and others, must have grown on angular detritus, at the time when the bed of the Bristol Channel was dry land. As the land sank beneath the sea, the trees were prostrated, and *Scrobicularia*-mud was deposited over the wrecks of the forest which, at intervals, may be seen passing on all sides, under low-water, down to the bottom

of the channel. From this it follows that some at least of the so-called submerged forests are only *littoral fringes* of what may have been a more or less continuous forest which once covered the present bed of the Bristol channel. The term Post-glacial, therefore, applies only to the upper parts (or the parts that can be seen between tide-marks) of a forest which before submergence grew to a greater or less extent over the whole bed of the Bristol channel. They would be more correctly called Post-glacial fringes of a pre-glacial or interglacial forest.

Origin of the so-called Raised Beaches of the Bristol Channel.—To avoid unnecessary complication we may, once more, go back to the time when the Bristol Channel was dry land, more or less covered with forests. The depression of the land commenced; and the sea rounded pebbles, and accumulated sand until the maximum amount of depression was reached. Then the sea stood at the level of what are now the raised beaches, and perhaps as high as the beds of loamy clay with angular stones called "head," above the beaches. The so-called beaches are merely beds of rounded shingle and sand, reaching twenty feet in thickness, which were accumulated on the tidal zone by the sea, and afterwards elevated above the present sea-level, in some places as much as thirty to forty feet. Mr. Mellard Reade lately saw instances near Watchet, (and I remember seeing instances,) in which the shingle-bed—or raised beach—was underlaid as well as overlaid by clay, with stones. I have no doubt that the under clay (which is very discontinuous) consists of portions of beach-clay which became covered with beach shingle, while the upper clay with angular stones represents the "*head*," which was distributed over the shingle partly by rain-torrents and partly by the sea. After the upheaval of the raised beaches the

sea stood at nearly its present level; and while the land remained stationary, or was very slowly sinking, the waves and currents commenced at the level of what is now extreme low water, to cut into the land (which sloped upwards as high as the raised-beach level) and to wear back the coast-line so as to make cliffs, exposing sections of the previously-raised beaches, as well as sections of the Triassic rocks on which the raised beaches may often be seen resting. The present tidal zone from the cliff-line to extreme low water is about half-a-mile broad, and, at extreme low water, the level at which the post-raised-beach denudation commenced is shown by the upper limit of the stumps of trees which extend downwards to the bottom of the Bristol Channel. During this latter process of destruction by the sea of its own former work, it has here and there been again accumulating shingle, which thousands of years hence, may possibly be upheaved so as to form a secondary series of raised beaches similar to those which have already been upheaved above its surface-level.

Raised Beach near Weston-Super-Mare.—At Birnbeck Cove encroachments by the sea have disclosed, or rather nearly destroyed, the last remnants of a genuine raised beach, which, as it may soon be no more, deserves a brief description. I found it represented at intervals along the top of the cliffs from the Flagstaff, as far as the bathing-cove, by small rounded flints, angular flints like chips or flakes, angular fragments of limestone, and loam, in places covered with a thin layer of rounded stones—the whole associated with land and sea-shells (*Littorina* and *Tellina*). The raised beach assumes its most decided character in Birnbeck Cove—a small recess, which in stormy weather is one day choked up with blocks and shingle, and the next cleared out by the

sea. It rests on the upturned and denuded edges of strata of limestone, and a conformable mass of trap from 30 to 40 feet thick. The following is the order of succession, in two sections, near to each other, where the different layers composing, or associated with, the so-called raised beach are exposed.

Reddish loam with angular and subangular stones, 4 feet.
Concretionary layers of sandstone, 2 feet.
Layer of nearly pure sand, 1 foot.
Conglomerate and breccia, consisting of rounded, subangular, and angular stones (with occasional flint chips) imbedded in a hard ochreous matrix, with sea-shells, and in the upper part numerous bones. The stones sometimes lie loose, but in general are firmly fixed. Thickness about 4 feet.

Arenaceous Limestone.
Limestone.
Hard Limestone (metamorphosed?).
Trap from 30 to 40 feet thick.
Sand with a few layers of stones.
Raised beach exposed.
Raised beach concealed under falling débris or grass.

Raised Beaches of Devon and Cornwall.—There are often large boulders in the "head" which covers these beaches, and some of them rest on the surface of the beach shingle. Mr. Ussher says that the average height of Cornish raised beaches is about 15 feet above the present sea-level. In the beaches the stones are generally rounded, in the "head" angular. The raised beach at Croyde, near Barnstaple, and many raised beaches in Cornwall, shew evidences of large boulders having been transported by floating ice. Mr. Williams found a block of granite in the base of the Croyde beach; which, according to some geologists, may have come from Lundy Island, and according to others from Cumberland. It was 6 feet long by 3 feet in thickness. Mr. Whitley has furnished me with a section of the raised beach at

Porthgwidden, near St. Ives, Cornwall, The uppermost consists mainly of decomposed rock, which rests on "head." The latter is made up of angular blocks of greenstone, mixed with smaller fragments, and loam, all from the hill-slopes above. Under the head comes the raised beach, which consists of perfectly rounded pebbles in a matrix of red sand. The beach rests on greenstone rocks. The whole is about 20 feet thick, and the bottom of the section is a little above high water mark.

Real or Supposed Subsidence of the Coasts of the Bristol and English Channels within Historical Times.—Sir Henry de la Beche was not only an accomplished and careful observer, but wrote a work on the art of observing. His opinion, therefore, ought not to be lightly regarded. He not only believed that beaches may have been raised since or during Neolithic times, but that parts of the coast of the Bristol Channel may have subsided since the time of the Romans. This opinion is likewise held by several good local observers. But before entering more fully into this subject, it may be desirable to explain the only two ways in which remains of the works or habitations of man (apart from damming out the sea by artificial embankments) may have come to exist on sea-coasts below the sea-level. First, the sinking of the coast after it was inhabited by man; second, the occupation by man of an area below the sea-level which the sea was prevented from overflowing by *natural* embankments accumulated by the sea itself. It may likewise be observed that many of the so-called submerged forests may have grown at or near their present level while the sea was *for a time* prevented by *natural* embankments from overflowing their sites. There are many sea-coast areas at the present day which are situated below either high or low-tide level.

Among these may be mentioned the neighbourhood of Hull, the Fen district, parts of the coast of Essex; Romney marsh, Pevensey level, and other places along the south coast; parts of the west coast of Lancashire, &c., &c. So far as the south-eastern part of the Bristol Channel is concerned, the question is, would the Romans be more likely to inhabit low areas of unhealthy marshland, at the risk of being overwhelmed by the sea or by fresh water floods, than to live in areas above or very little depressed below the sea-level? The following instances of Roman remains, which have been found below the present sea-level, are only a few out of the many which might be stated. Mr. Baker gives the following section near Bridgewater:—

	FEET.	
Fine silt	16	=26 feet.
Peat	1	
Soft silt	9	

Gravel, with bones, shells, and Roman pottery.

Mr. Anstice discovered traces of a Roman road across Brent Marsh 6 feet below the present surface. According to Mr. Straddling vessels now pass over the old carriage road to Stert Point.

Insulation of St. Michael's Mount, Cornwall.—At the British Association meeting in Birmingham in 1865, Mr. Pengelly read a paper of which the following is an abstract:—

"St. Michael's Mount is an island at every high water, and, with rare exceptions, a peninsula at every low water. It is about one third of a mile from the mainland. Its name in the ancient Cornish language—"Caraclouse in Cowse," or the "Hoar Rock in the Wood,"—is entirely inappropriate at present, and betokens a change in the geography of the district since

Cornwall was inhabited by a people speaking a language which survived until a very recent period.

"The Mount is undoubtedly the "Ictis" of Diodorus Siculus, whose description is still so very appropriate as to render it probable that two thousand years have produced very little change.

"The insulation must have been effected, of course, either by the encroachment of the sea or by a subsidence of the district. The former hypothesis requires such an enormous amount of time, and is so utterly opposed to various geological facts, as to render it eminently probable that, since Cornwall was inhabited by a race speaking the British language, St. Michael's Mount was insulated by a general subsidence of the country."

Submerged Forests and Raised Beaches along the South coast of England.—There are instances of raised beaches in Mounts' Bay and Falmouth Harbour, on Plymouth Hoe, at Hope's Nose, near Torquay; and on the Isle of Portland. Off Selsea Bill there is not only a submerged forest, but a marine deposit with shells, indicating a warmer climate than that now prevailing on the coast. Above the marine deposit there is a bed of yellow clay which contains immense and far-transported boulders of syenitic granite, so-called greenstone, &c.

Inter-glacial Age of the Raised Beaches of the South-West and South of England.—From the "head," with angular boulders resting on these beaches; the granite boulder under the Croyde raised beach, near Barnstaple; the interposition between deposits with angular stones of the raised beaches, near Watchet, &c.; it may safely be inferred that the shingle and sand of these beaches was deposited between two glacial periods when ice floated along the sea-coasts.

Origin of the Terraces of the South Downs.—As an undoubted raised beach was discovered not long ago, by Professor Prestwich, on Portsdown Hill, at a height of 125 feet above the present sea-level, and as this beach lies some distance inland from the main part of the coast-line, there can be no reason for doubting that farther inland other raised beaches may yet be discovered. Some time ago—perhaps too hastily—I advocated the theory (in the *Geological Magazine*, and afterwards in my *Scenery of England and Wales*,) that the numerous terraces of the South Downs, called *lynchets*, were produced by sea-currents or waves. One of the best examples of these terraces occurs near Stockbridge, in Hampshire. That they were not made in the middle ages by different tenants cultivating narrow strips of land separated by slopes, was clearly shown by Mr. Baigent, of Winchester, who could find no records of their having been cultivated by man, after much searching into ancient documents. It is to be regretted that while geologists are wasting their time in going over districts which have often been described, without being able to discover anything really new, they should overlook such truly interesting problems as the origin of the terraces of the South Downs.

Changes of Level along the Old Severn Strait.—Farther south than Gloucester there is scarcely anything that can be called drift, with the exception of a few transported stones, chiefly angular. Between Gloucester and Oxford, Professor Phillips found northern drift on the oolitic hills, 750 feet above the sea; and Mr. Lucy, a very careful observer, found northern drift on the summit of Cleeve Cloud, 1,134 feet, shewing the submergence of the hill to that extent. At Strethill, near Buildwas, Mr. Maw found marine shells in drift at a considerable height above the sea, and they have been found in other

places in the neighbourhood. Near Burton (not far from Much Wenlock), Mr. Maw found numerous Eskdale granite pebbles at a height of 800 feet, which could only have been transported by floating ice; and I have noticed granite erratics between there and Church Stretton at nearly the same height. Farther north, around Shrewsbury and Oswestry, and in the Ellesmere eskers, marine shells have been found. It is certain that in the comparatively low ground between the Pennine hills on the east, and the Welsh hills on the west, the sea must have lingered a long time to be able to accumulate so much rounded drift. At that time Wales must have been an island, but it was not until the submergence had reached the height of the high-level drifts that the sea penetrated into its numerous valleys so as to convert it into an archipelago, that is supposing the sea had not been kept out by an immense expanse of land-ice.

High-level Marine Drifts in Macclesfield Forest.—East of the "Setter Dog Inn," near Macclesfield, Professor Prestwich, in 1862, discovered sand and gravel with sea shells at an altitude between 1,100 and 1,200 feet above the sea. Mr. Sainte, of Macclesfield, in his valuable work, entitled *Rambles round Macclesfield*, gives the following section, about 32 feet deep, of the drift-deposits:—

Ferruginous clay, gravel, and small boulders.
Red sand.
Gravel and drifted shale.
Loamy sand.
Drifted shale and gravel, with small boulders, and a few fragments of shells.
Sand and loam.
Coarse sand, with boulders and pebbles.
Gravelly clay, with a few boulders.
Dark sandy gravel, with many shells.

High-level Drifts on Halkin Mountain.—From Moel-y-Gaer in the south, to beyond Holywell in the north, a distance of more than six miles, the comparatively flat summit of the mountain is more or less covered with rounded gravel and sand, which here and there contains a few shell fragments.

To the west of Holywell, a decidedly lower boulder-clay (brown or yellowish brown) with local angular stones, and a few rounded erratic pebbles, may be seen filling up hollows, and penetrating into the cavities and rents of the mountain-limestone. Close to Brynford (near Canol-y-mynydd on the Ordnance map), at a height of nearly 800 feet above the sea, there is a beautifully curvilinear series of sand eskers, containing fragments of sea-shells, chalk-flints, and drifted coal. One at least of the sand eskers is capped with coarse gravel. A strikingly perched esker of considerable height may be seen near the south end of Halkin mountain at an altitude of about 950 feet above the sea (Moel-y-Crio on the Ordnance map). The ground for a considerable distance from this esker declines in all directions, excepting on one side where, for a short distance, it is horizontal.

High-level Marine Drifts on Minera Mountain.—From about 1,000 feet to 1,350 feet above the sea-level, on the eastern slope of this mountain, one might traverse the ground for years without seeing any indication of marine drift. Having, however, accidentally heard that there were several gravel pits scattered over the slope, I commenced a search which, during many visits, resulted in finding a number of gravel-pits lurking in the sides, or on the summit, of sand and gravel knolls. In two of these pits I found shell-fragments. Between the gravel knolls a number of brook channels shewed sections of

fine gravel under clay, and I have now little doubt that gravel is extensively distributed under the clay. There were large boulders on the surface, but I could see none regularly imbedded in the gravel and sand. I wrote two papers on the subject, which have lately been published in the *Quarterly Journal of the Geological Society*. The rounded gravel and sand extend from N.N.E. to S.S.W. over an area nearly five miles in length. Near Mountain Lodge I saw the rock (carboniferous sandstone) exposed in a quarry. Its surface had been broken up into angular fragments by glacial action, and I have no doubt the sea, by this cause, was furnished with the stones which it gradually rounded into pebbles. The drift often rises up into mounds which often occupy perched positions. Towards the south end of the drift-covered area the rounded gravel is only in some places visible where it has been exposed in brook channels, or in other positions where it may be seen extending under clay.

High-Level Marine Drifts on Moel-Tryfan.—What I have to say to-night concerning these drifts, will consist of remarks on phenomena which have been only slightly noticed, or not noticed at all in my papers in the *Quarterly Journal of the Geological Society*. One important fact is the extent to which the pebbles have been derived from the Cambrian conglomerate, of which a part of the mountain consists. Other pebbles have been derived from neighbouring hills, and a considerable proportion consist of both Eskdale and Criffell granite from Cumberland and Scotland. The largest boulders on the surface of the clay have been partly derived from the immediate neighbourhood. The drift, like all drift of the same kind, generally rises into mounds. In sections I saw exposed during my third visit, the relation

between the overlying drift and the edges of the nearly vertical slaty laminæ could be clearly seen, and furnished an answer to Dr. Hick's remarks at the meeting of the London Geological Society when my paper was read. The slates, apparently, extend under the drift as far as the north-west brink of the hill. The upper part of the slaty laminæ had evidently been broken off by a violent force such as that accompanying the stranding of an iceberg, and laid at all angles between the vertical and horizontal, so as to form *a bed of slate chips about three feet thick.* There were the clearest indications of sudden and violent action which extended to the laminated fine gravel and sand, for the latter were contorted, doubled up, and inverted in the most extraordinary manner. The phenomena on Moel-Tryfan furnish a death-blow to the theory that land-ice could plough up shells from the bed of the Irish Sea and deposit them on the top of the mountain, for the matrix of the shells differs from any part of the pre-glacial bed of the Irish Sea. Land-ice able to accomplish this feat, must likewise have been able to round and arrange in laminæ and strata the local stones it found on the top of the hill, or to have created these stones during its uphill march.

Concluding Remarks.

With regard to the height at which sea-shells and marine drifts may be found in North Wales, I have to correct an error which has been copied from one book into another. The error is, that Ramsay found sands and gravel up to 1,800 feet above the sea, undistinguishable from what exists on Moel Tryfan, with the exception of shells being absent. The truth is, that Ramsay could find no drift like that on Moel Tryfan at a greater altitude, but up to 1,800 feet he saw clay

similar to that in which he had found shells on Fridd Bryn-mawr (west of Llanberis) at a height of about 1,000 feet above the sea-level.

I have found boulders, which must have come from Scotland, on the top of Moel Wnion, 1,900 feet above the sea, accompanied, at a somewhat lower level, by a kind of shingle, which is probably of marine origin.

Around Llangollen I have found Arenig Felsite boulders up to about 1,900 feet, so that the evidence furnished by boulders would make the extreme extent of the submergence of North Wales about 1,900 feet.

A TRAVERSE OF THE YORKSHIRE DRIFT.

By T. Mellard Reade, C.E., F.G.S.

Last summer, with the object of supplying some of the "missing links" necessary for the comprehension of the North-West of England Drift, I traversed the Ribble Valley from Ribchester to Moughton, beyond Settle. The information gained in Ribblesdale is embodied in my paper, Part II., "Drift of the North-West of England," which, I anticipate, will be published in the May number of the "Quarterly Journal of the Geological Society."*

My present purpose is to continue the traverse from the point where I left off in Ribblesdale across the Pennine Chain and the Vale of York to Scarborough, and then to touch upon the drift deposits between Scarborough and Filey, and in Holderness from Flamborough Head to a point some seven miles south of Bridlington.

---

* See Q. J. G. S., Vol. xxxix., pp. 102–106.

Until I arrived at Skipton I saw nothing in the way of drift particularly worth noting. The mountain limestone hills, with the exception of the erratic or travelled blocks lying scattered about the surface, seem to bear little trace of drift. It is only in the river valleys that we see it in force, but when we get to the millstone grit and carboniferous sandstones on the Yorkshire side of the Pennine anticlinal the drift deposits increase.

Directed by my friend Dr. Ricketts, I climbed to the top of Embsay Crag, and, descending by a brook, found good sections all the way down to Whitfield Beck Mill. First, great blocks of grit, over which the water purled and poured in picturesque and refreshing cataracts. Then sandstone blocks mixed with sand—the *débris* of the rocks above—and here and there a piece of limestone, in these cases erratics. At last I came upon the section to which Dr. Ricketts had specially drawn my attention, of which I give you a sketch. *A.* are limestone shales, much softened by water. *B.* is the moraine-like drift, containing white scar limestone and dark limestone, but principally grits embedded in a sandy matrix.

In the valley of the river Aire sections are to be seen of river gravels, apparently nearly wholly of limestone, and of that uncertain age later perhaps than the glacial period, yet, no doubt, dating far back in post-glacial times.

On the river Wharfe are to be seen huge banks of shingle, sand, and gravel, which the river has worked its way through, and which may be examined more in detail in the many gravel pits that have been dug into them. The pebbles are of rounded limestone and sandstone, and are mixed with gritty sand. It may be taken as a general rule that higher up these rivers, and nearer their sources in the mountain limestone, the pebbles of

that rock increase, while in their passage down the rivers through other formations they get more and more intermixed with the characteristic local rocks. The river banks are cut into terraces, but I hardly think they are so definitely marked as regards level, as stated in the Survey Memoirs.

At Grassington, higher up the Wharfe, a section in the river bank shows the drift to be of a more calcareous nature. There were some faint striations in the stones, which were rounded boulders and pebbles.

At the Grassington lead mines occur some very singular circular pits, penetrating the millstone grit, here nearly horizontal. They are cylindrical holes, about twenty yards in diameter, the sides being vertical as regards the rock, but funnel-shaped in the overlying drift. Mr. Trevethan, the manager of the mines (now unfortunately closed), tells me they penetrate the limestone below. This remarkable phenomenon is not easy of explanation. Lower down the hill is a cañon, the millstone grit being cut down in vertical walls to the limestone. The stream that crossed this cañon has now taken another course in the limestone underground, and no water ordinarily flows down it; but a short time ago a great flood occurred, which, finding insufficient vent down the ordinary channel, burst into the old course, washed down a roadway crossing the cañon, and moved boulders of three tons weight, lying in its bed, at least ten yards. There had been no water in the cañon for forty years previously.

At Ilkley there is nothing special to draw attention to, but a walk up the river as far as Bolton Bridge, shows river cliffs at various levels cut out of the valley drift. I confess I again failed to see the regular terraces described in the Survey Memoirs. Above Ilkley, on the

high ground known as Burley Moor and Hawkesworth Moor, there are, according to the Survey Memoir, curious ridges of gravel. They "commence nearly due south of Ilkley at an altitude of 1,175 feet, and range first in an easterly and then in a southerly direction to the village of Hawkesworth, where they terminate at an elevation of only 600 feet above the sea. They lie partly in Boulder-clay and partly on ground free from this deposit."*

In crossing the plain of York from Knaresboro', by railway, we see at once that we are on ground geologically like the Lancashire plain. Between Cattal and Hammerton Stations there is an expanse of New Red Sandstone, but as far as York there are no other evidences of the underlying formation, except in the nature of the Boulder clay.

At York, Mr. Walter Keeping, F.G.S., of the museum of the Yorkshire Philosophical Society, very kindly took me to see what exposures of Boulder-clay there were in the neighbourhood. This clay is very like the lower bed of our Low-level Marine Boulder-clay, being sandy and "short" in texture. It is of a red colour. The contained stones are principally of millstone grit and carboniferous limestone, with some few far travelled rocks, one of which Mr. Keeping identifies with a porphyritic felstone he has seen in Norway; nearly all I saw being rounded, but I understood I only saw the top part of the Boulder-clay. We also examined a gravel pit at Bishopthorpe Road, and here again the shingle, boulders and gravel were nearly all of grit and limestone, with a few volcanic ash pebbles from the Lake District. In this deposit Mr. Keeping informed me was found the skull of a Polar Bear. Shap granite boulders are found in the vale of York.

* Explanation of Quarter Sheet, 92, S. E., p. 12.

Mr. Keeping and Mr. Moiser, F.G.S., shewed me what are called the "Warp" clays of the vale of York. They are used for brick and tile making. The following is a section at the Heworth Brick and Tile Yard compiled from my own observation, and from information from Mr. Moiser :—

Surface about 50 feet above O. D.

Sand 3 feet—in some localities this is 20 feet thick.

Imperfectly laminated clay—"Warp" used for making bricks—10 feet.

Laminated clay used for tiles, 7 feet—a grit boulder, 18 inches diameter, was found at the base.

Gravel, 4 feet.

Laminated clay, 3 feet.

Gravel unbottomed.

Mr. Moiser informs me the warp clay lies in hollows of the Boulder clay, levelling them up. Bosses of boulder clay rise through the warp. In fact, one of these bosses was mistaken by local antiquaries for a tumulus.*

Excavations for a gasholder on the banks of the river Ouse shewed about sixty feet of fresh water deposits, with a bed of peat, and an old road formed of branches. Fresh water shells and stags' horns were found in the deposit.

On Strensall Moor a well was being bored for the War Department, with the view of forming a camp there. The following is a section (the depths being all from the surface) :—

	FT.	IN.
Sand	6	3
Blue Clay	8	6
Warp	19	0

	FT.	IN.
Unctuous brown clay, partly laminated "warp" (?)	41	0
Boulder clay with erratics	54	0
Sand	55	0
Boulder-clay, red and short	67	0
Blue bind—Trias	94	0
Do. a little different shade	112	0

The boring tools were in light grey sandstone at a depth of 260 feet.

A well section at Hotham Brewery, York, kindly supplied to me by Mr. Moiser, shewed 57 feet of Boulder-clay and warp resting on Triassic sandstone.

Mr. Keeping also very kindly gave me the photographs I now exhibit of railway cuttings in the Boulder-clay at York. Nos. 1 to 4 shew clays enclosed in sand and much contorted. The limestone boulders in No. 1 shew very marked ice scratches.

No. 5.—Shews a central anticlinal band.

No. 7.—Mass of angular sand embedded in Boulder-clay.

No. 8.—A long section; shewing a mass of pebbles on the left amounting to several cartloads, and curious contortions and false bedding to the right.

Mr. J. Edmund Clark, in a paper read before the Geological and Polytechnic Society of the West Riding of Yorkshire, 1881, gives details of two interesting sections of fluviatile deposits near the river Ouse—one at Brett's Brewery, the other at the waterworks engine house—showing 63 feet of deposit, the surface level being 20 feet above the river's summer level. Mr. Clark says, p. 438: "The Ouse, as was pointed out many years ago, is from 60 to 70 feet above its pre-glacial level." Thus we see the phenomenon which I have shewn occurs on

the Mersey* is repeated on the east coast in the Tyne, Tees, and Ouse.

Mr. Clark also describes in detail the glacial sections shewn in the photographs I exhibit. He concludes: "The glacial beds here described most resemble the Purple Boulder-clays of Messrs. Searles V. Wood and Harmer. Their appearance, however, indicates a deposition from floating ice rather than, or as well as from, the *moraine profonde* of an ice sheet." He considers the drift to have been principally from the North-West.†

Mr. Clark describes a bed of manganese occurring in post-glacial (?) gravels on the banks of the Ouse, 25 feet below the surface (p. 427).

I made a stay at Malton to see the Oolites. There is an absence of drift in this area. At Seamer Station a splendid boulder of Shap granite is to be seen in the station master's garden.

Coast Sections.—Between Filey and Scarborough numerous sections of the drift may be seen, enabling us to form a pretty accurate general idea of its nature and mode of occurrence. Commencing at Filey, we see a reddish purple clay imperfectly bedded, resting upon a purple clay of a more amorphous nature. Further on, at the top of the Nase, Filey, we see the Boulder-clay resting upon the Coralline Oolite. It is here split up with two parallel bands of sand. But the most

* "Buried Valley of the Mersey."—Proc. of L'pool. Geol. Soc., 1873.

† Since this paper was written, Mr. Mackintosh, our President, has sent me reprint of a paper of his, "On the Nature Correlation and Mode of Accumulation of the Drift Deposits of the West Riding of Yorkshire." He describes two Lower Boulder-clays—a brown and a yellow. He says: "I believe that the blue and yellow Boulder-clays run under the extensive beds of dark laminated clay and sand and gravel which spread out over the Vale of York."

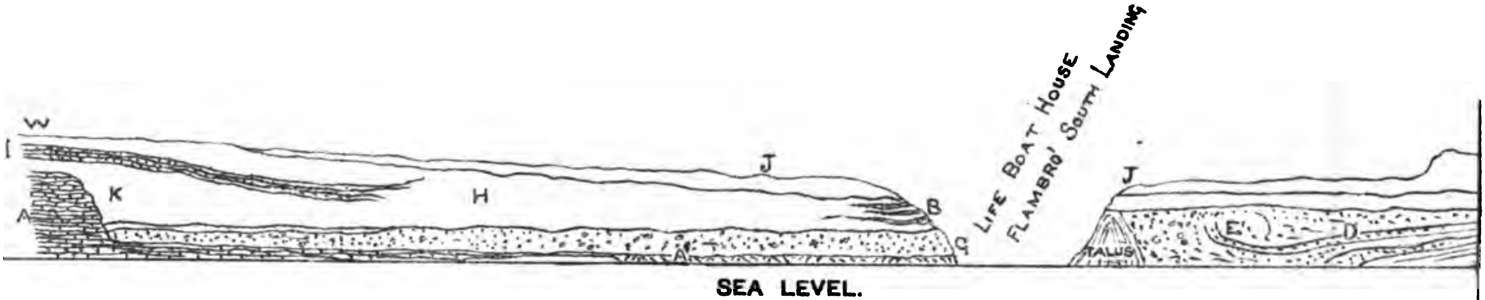
noticeable feature to me was the way in which the clay denudes and stands up in sharp ridges and pinnacles, the result of an imperfect system of jointing, together with the hard sandy nature of the material. Such denudation-forms would be impossible in our Boulder-clay. Further on the top of the cliffs shew the Upper Passage-beds of the Oolite thrown up into small anticlinals and otherwise contorted, the effect, it is considered, of ice action.

In Osgodby Nab, almost perfectly parallel lines of jointing may be seen in the Boulder-clay on the shore; having a direction magnetic E. and W., they extend into the cliff. About a quarter of a mile further on the jointing shews again on the shore, now due E. and W., and all the Boulder-clay at the base of the cliffs is deeply gashed with it. At one place the jointing took parallel curved lines, and it extends through the denuded bosses left on the shore. We found shell fragments in the tilly clay in Cayton Bay, mostly consisting of *Cyprina islandica.* Between this point and Scarborough there was nothing of importance to note in glacial geology; but for lovers of the picturesque and those interested in the Oolitic geology the work has a surpassing interest.*

Flamborough Head.—The next point of the coast I examined was Flamborough Head. Here the purple clay (I use the term in a non-geological sense) rests upon the cliffs of hard chalk, and is full of chalk pebbles. Passing southwardly along the shore under the grand chalk cliffs, we come next to the South Landing, odorous with decomposing remains of fish, and here we see a very

* The solid geology of the coast is admirably described by Mr. Wilfred H. Hudlestone, F.G.S., in "The Yorkshire Oolites,"—Proceedings of the Geologists' Association, vols. iv. and v.

SKETCH SECTION NEAR FLAMBRO' HEAD, 1882.



instructive and interesting section of the drift and its junction with the chalk. I reproduce this section:—

A.—Chalk.

A''.—Chalk much shattered and covered with chalk *débris*, which obscures the structure.

B. B.—Stratified beds of chalk, gravel, and sand.

C.—Rolled rubbly chalk.

D.—Chalk *débris*, rounded and subangular; two erratics taken out at D.

E.—Chalk *débris*, contorted.

F.—Boulder-clay, with sand beds, *ff*.

G.—Chalk shingle with erratics.

H.—Sand.

I.—Curved beds of chalk shingle and gravel included in the sand.

J.—Purple clay.

At K. the drift butts up against a chalk cliff.

Nearer to Bridlington, a stream at right angles to the shore shewed purple clays resting upon chalk, and split up with included beds of chalky gravel and shingle.

The next excursion I took was by a boat to beyond Barmeston Drain, south of Bridlington; walking back along the shore, I noted down a continuous section of this drift as far as Bridlington.

The Boulder-clay at the base is of a blue-black color, and gradually shades up into a light reddish brown. But the colour seemed more influenced by the moisture in the clay than due to the difference of its composition.

It is to this part that Mr. Searles Wood's Hessle clay extends, according to his section.* At the N. of Barmeston Drain a laminated clay comes in, which lies in an

* "The Glacial and Post-Glacial Structure of Lincolnshire and S. E. Yorkshire." Wood and Rome.—Q. J. G. S., 1868, p. 148.

eroded surface of Boulder-clay. This is more or less continuous to Bridlington, and comes in in great force immediately to the south of that place. Lying upon the Boulder-clay and laminated clays are at intervals post-glacial deposits of marl and peat, evidently formed in shallow meres that have formerly occupied this part of the Holderness. The peat is in some places covered with a flinty gravel, holding broken fragments of sea shells, about 4 feet 6 inches above the present beach. The peat also contains mussel shells.

Mr. Lamplugh, who has worked very assiduously at the drift in this neighbourhood, directed my attention to a section displayed through the washing away of part of the sea wall of Bridlington Quay, immediately in front of the Alexandra Hotel. This shewed what he calls, using Mr. Searles Wood's nomenclature, the "Basement-clay of Holderness," upon which rests the "Purple clay." A line of erosion distinctly separates two clays, the lower being of a more tilly nature. North of Bridlington Quay, white cyclas marls are seen resting upon ferruginous chalky gravel, which again rests on the purple Boulder-clay.* Those who wish to study this question should, of course, consult the late Professor Phillips' classical work on the Geology of Yorkshire, Part I., "The Yorkshire Coast."

At this point my observations terminated; and having given you a general outline of what I saw of the Glacial Geology of Yorkshire, I will now proceed to analyse the

* Much information, of a very detailed and minute nature, may be obtained from the following papers:—

"Glacial Sections near Bridlington," by C. W. Lamplugh.—Proc. of the Geol. and Polytec. Soc. of the West Riding of Yorkshire, 1881.

"The Divisions of the Glacial Beds in Filey Bay."—*Ibid.*, 1879.

"The Boulder-clay at Bridlington."—*Ibid.*, Geol. Mag., Sept., 1879.

"The Bridlington and Dimlington Shell Beds."—*Ibid.*, Dec., 1881.

facts, and attempt, if possible, to extract some information from them.

In the first place, I may say that the course of my traverse was determined by the fact that I had discovered, as I thought, on the western side of the Pennine chain, a relation between the nature of the drift occupying certain areas and the rocks lying in the river basins and valleys which must have fed these areas with detritus. These views will be published in the May number of the Quarterly Journal of the Geological Society, so I need not here repeat them.*

If this view were correct, it was only natural to expect that the same phenomena would be repeated, modified by local peculiarities of ground, on the eastern side of the Pennine chain.

It will be seen from what I have stated that the upper portions of the valleys of the Aire and Wharfe, as in the Ribble, are almost exclusively filled with drift, whether of Till or Boulder gravel, derived from the immediate rocks of the drainage area mixed with but a few erratic stones that have come from other watersheds. As the rivers are descended the drift becomes of a more composite character from the mixture of other varieties of rock the rivers cut through. It is when we get upon the great low-lying plains in the east of England, as in the west, that the mass of Boulder-clay occurs in which we find such an extraordinary assemblage and medley of materials. Rocks of all ages, from the cretaceous downwards—Granites Syenites Gneiss, Felstones, Trappean rocks, Porphyries, and even Serpentines. A quarry of specimens, so to speak, brought to

* See Drift Beds of the North-West of England.—Quarterly Journal of the Geological Society, Vol. xxxix.

the geologist's door from all parts—north, east, and west. If again we examine the nature of the clayey material, we also find that it is composed of materials brought down by the rivers from the higher lands, mixed with the local matter derived from the underlying rocks.

In the Vale of York, for instance, we see that the bulk of the contained stones are of carboniferous limestone and grits in a much larger proportion than in the drift in our neighbourhood. These have evidently come down the ordinary drainage lines of the country, but these lines have been crossed by far-travelled stones from Cumberland and the east of Scotland. The red colour of the drift is largely due to the mixture of the detritus of the Red Sandstone beneath, which has been worked up into it.

When we pass to the coast the same thing occurs, excepting that there is a larger admixture of travelled blocks contained in the drift. The oolitic and cretaceous rocks here form the bulk of the inclusions, and there exist more undoubted signs of the sea in the shape of shell fragments and foraminifera. The underlying rocks supplied *débris* to form the lower beds of the drift, as may be observed in the section near Flamborough Head.

Giving all due heed to the opinion of those who ascribe all this multifarious work to land ice and that alone, it appears to me that the weight of evidence is strongly against their views. If due to an ice-sheet—a disrespector of watersheds—should we have the inter-dependance between the drift and the present drainage lines that I have shewn exists? Could an ice sheet from Scandinavia bring the bulk of the matter forming the Boulder-clays from the east? It seems to me that such an explanation is invoking a tremendous agency

to account for the presence of a few Norwegian rocks. On the other hand, if we bring an ice-sheet from the north-west to account for the distribution of Shap granite boulders over Yorkshire, that have evidently travelled through the pass of Stainmoor, we ought to find also in the Yorkshire drift a large proportion of rocks from the south west of Scotland—granite from Criffel and Dumfries, intermixed with purely Lake District rocks.* My limited observations do not confirm this, though it is possible the Galloway Drift may be met with to a small extent, as the general direction of the drainage lines on the N.E. of the Pennine chain is in that direction. But, as a matter of fact, I did not observe one single piece of granite until I reached the plain of York. Such an ice-sheet from the north-west would have crossed the upper parts of the valleys of the Lune and the Ribble, and we should expect to find similar evidence of its former existence within them. Nothing of the sort occurs. It is in the low-lying clays of Lancashire as in those of the east coast that these far-travelled erratics are found in profusion, and not until we get as far south as the Macclesfield Hills do we find them in any abundance at a higher level.

But why go out of our way to seek for an agent that *might* have done the work, when an obvious and simple explanation better meets the conditions of the case? Is it possible for land ice to have worked up the rounded chalk pebbles and shingle underlying the purple clay at Flamborough Head? If it came from the north-west, in which way could it introduce marine shells into the clay at Bridlington and Cayton Bay, or bring gneiss

* This occurs in the Eden Valley, but more particularly in its lower portion.—See "The Glacial Phenomena of the Eden Valley," by J. G. Goodchild.—Q. J. G. S., 1875.

from Norway? The drift of the plain is too much of a medley, it contains fragments from too many quarters, to be explained by such intractable machinery as land ice. Nor is it easy to conceive if, on the other hand, our explanatory agent be a Scandinavian ice-sheet, how a vertical cliff facing its course, such as my section shows at Flamborough Head, could have retained its form or the shingle worn from it remain lying at the base. Surely such a mighty abrader would have effaced it, and landed portions of the chalk oolite and lias on the eastern flanks of the Pennine chain.

It appears to me that the phenomena on the east of the Pennine chain repeat those on the west; that the drift in both cases only dates back to the time of the existence of local glaciers in the high lands; that the rivers then (as now) brought down, aided by frost, detritus which was distributed in a comparatively shallow sea, over which floated drift ice. Ice may have radiated from the Lake District, so that the Shap granite boulders may have been conveyed through Stainmoor by land ice to the sea, or until they could be taken up by river transport. This degraded matter from the high lands became mixed with the detritus of the local rocks of the plains, worked up by the sea during an extremely slow subsidence. The degraded matter of the plains may—and probably did—accumulate sub-aërially before submergence, through the action of atmospheric agencies. Land ice, if it existed, must have pre-dated the Boulder-clays of the plains; but that it shrank to local glaciers before the submergence, and left the surface of the land exposed to atmospheric waste intensified by frost, is, I think, more than probable. In a former paper I attempted to show how the enormous masses of chalk found in the Cromer Drift were quarried out of cliffs and

escarpments;* and similar agencies must have acted at the same time on the surface of the country, breaking up the rocks. That they did so, I have only to point to the shattered condition of the surface of the chalk underlying the purple clay of Flamborough Head. It is eminently confirmatory of this view that mammalian remains found in Norfolk have been taken out of the crevices of the chalk which had been disturbed by ice action, showing that, so far from the country being wholly occupied by ice, large mammalia roamed over it. Remains of the Mammoth and Red Deer, and even *Elephas primigenius*, have been found in "Chalk Rubble, Norwich." †

If the Boulder-clay and sands of the plains—which I have called the "Low-level Boulder-clay and Sands"—were laid down in the sea in the way I have attempted to describe, the peculiar assemblage of rocks found in them present no difficulties. In fact, they occur in the positions that might have been predicated.‡ Their intercrossing presents no difficulties—a change of wind only is required to bring them from Norway, Scotland, or the high ground of Cumberland. Compared with what we see about here, the contained rocks in the Yorkshire drift are not so numerous, so large, or so distinctly ice-marked. The clays are also full of fragments of chalk, oolite, and lias, and fossils derived therefrom, in a remarkably good state of preservation. In our own clays the lower beds are mixed with red sand, the *débris*

* "The Chalk Masses in the Cromer Drift."—Q.J.G.S., 1882, p. 222–238.

† "Memoirs of the Geology of the Country around Norwich," by H. B. Woodward, pp. 137–8.

‡ The late John Phillips, discussing this question, "Geology of Yorkshire," Part I., Sec. Edition, 1875, p. 166, says: "The mixture of stones of different sorts, brought in different directions, is what requires explanation."

of the Triassic sandstone, as appears to be the case in the Vale of York. The form in which the *débris* of the local rocks occur in the drift is largely dependent upon the nature of the rocks themselves.

Thus then, in my opinion, the views I have put forward regarding our own drift may be legitimately used to explain that of Yorkshire. It is the same thing, locally modified by physiographical peculiarities.

The "Warps" of the Vale of York and the laminated clays of Holderness represent the later phase of conditions. It is not improbable, as they seem to lie on eroded surfaces of the clay below, that they may have been laid down in shallow tidal waters during emergence. They contain few or no stones—only concretionary bits of carbonate of lime, not inaptly, from their shape and size, called "gingers." The underlying Boulder-clay may have been eroded by tidal currents and wind waves, previously to the land being placed by emergence at the exact level required to produce the extensive sheets of laminated clay. Nowhere that I have seen in Lancashire are there any beds to parallel these laminated clays, for nowhere do the requisite conditions obtain.* They evidently result from quiet tidal overflows of large tracts partially land-locked.

I have said nothing as to the division of the beds of Low-level Boulder-clay and Sands which Messrs. Searles Wood and Rome have adopted. There are certainly more marked distinctions to be seen on the east than the west coast, but I saw nothing in the course of

* Occasional laminated beds occur in the Boulder-clay of Lancashire, and I have some very good specimens taken from excavations in a street in Manchester, given me by Mr. R. D. Darbishire, but the extent and depth of this clay I cannot ascertain.

my traverse to disturb my view that these drifts are practically a continuous deposit. I very much suspect, as pointed out to me by Mr. Jukes Browne, that in many cases contemporaneous erosion has been mistaken for unconformity. From what I saw of the so-called Basement-clay of Holderness and the overlying purple clay their separation can be fully explained in this way, but it is quite possible that the masses of sand and clay included in the Basement-clay which originally gave it the name of Bridlington Crag may have been derived from an older deposit, or they may have been littoral masses of the same age frozen into shore ice, torn up and deposited in deeper waters. In this way the preservation of the shells may have occurred. After reading Mr. Lamplugh's description, this explanation suggests itself to me as most likely the correct one, for in the surrounding Basement-clay fragments of the same shells are found. The included masses "seemed to have been a stratified deposit" and "a few even of the larger shells were in an absolutely perfect state of preservation; whilst those which were broken were probably broken either during the life of the animal or very shortly after."*

Minute observations of the drift in various localities are of the utmost value, and it is to local observers we are usually indebted for them; but to understand this phase of the earth's history it does not do, as I soon found out, to rely entirely on what we see at home—to theorise from limited observation. On the contrary, this mass of apparent confusion, called the drift, which refuses to yield to detached investigation, is, as I hope I have shewn, related to the larger features and physiography of the country, and capable of a full and simple explanation.

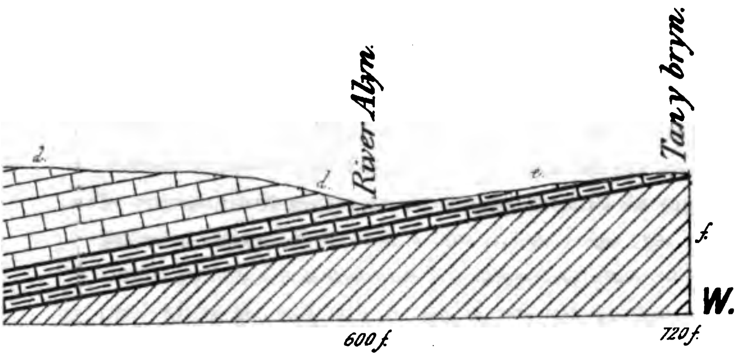
* Geo. Mag., 1881, pp. 539-40.

THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF FLINTSHIRE.

THE COUNTRY TO THE NORTH OF MOLD.

By G. H. Morton, F.G.S.

The Typical Section (Plate I.) showing the contour of the country, and the subdivisions of the Carboniferous Limestone and Cefn-y-Fedw Sandstone, as they occur between Gwern-y-mynydd and "The Loggerheads," on the south of the Mold and Ruthin road, was described in connection with the country to the south of Mold. The country to the north presents the same subdivisions, though an examination of the natural exposures and quarries shows the succession under a different aspect. On the rising ground, towards Hafod, the conglomerate sandstone at the base of the Lower Cefn-y-Fedw Sandstone crops out on the surface, and on the west the Arenaceous Limestone is well exposed in some quarries along the strike of the strata, while near the Cat Hole Mine the lowest bed of sandstone crops out and forms a low ridge, about fifty feet high, on which there is a small plantation. About a hundred yards to the west the highest beds of the Upper Grey Limestone are exposed, with the usual corals and other fossils. A little further on in the same direction, the lower beds of the subdivision crop out and are of a lighter colour than usual, closely resembling strata on the same horizon near Maes-y-safn. The Middle White Limestone then crops up as the ground rises and forms Cefn-mawr, a hill with a precipitous escarpment towards the west. No precise line can be drawn between the Upper Grey and the Middle White Limestones, for the strata are not continuously exposed.



LD.

riuistria. Fenestella plebeia. &c.

. Lithostrotion irregulare. L. junceum &c.

chburyi. &c.

eolites septosa. Syringopora geniculata &c.

Mile. Vertical Scale 1 Inch to 1000 feet.

ip of the strata 16° E.

Opposite "The Loggerheads" the Middle White Limestone forms the perpendicular cliff nearly 200 feet high, which with about 100 feet of higher beds, and 210 feet of limestone proved below the adit level in the Glan Alun Mine, give a thickness of 510 feet without reaching the bottom. The actual base of the limestone can be seen in the bed of a stream at Pwll-y-blawd, and strata a little above it in an old quarry at Tan-y-bryn, both places being about half-a-mile to the west of the limestone escarpment. At "The Loggerheads" the strata dip 18° S.E., at Tan-y-bryn 14° S.E., but at Pwll-y-blawd it is doubtful, though it seems to be 24° E.; and it does not seem that there can be more than 200 feet of limestone below that proved in the mine. The fault, or Caleb Bell Cross-course shown on the section (Plate 1) and on the 1st edition of the Geological Survey Map is not visible on the surface, but was probably discovered in the mine at Tyn-y-Coed, which is now abandoned. If there is such a fault, it is probably a downthrow to the west and causes the limestone to appear somewhat thicker in that direction. However, the 510 feet of limestone at "The Loggerheads," and the 200 feet between there and Pwll-y-blawd, seem to be the most reliable measurement of the thickness, and probably sufficient to include the Lower Brown Limestone, but which is so partially exposed at Pwll-y-blawd that little can be seen of it.

The base of the Carboniferous Limestone extends further west than shown on the Geological Survey Maps, and in 1881 there was a small opening in white limestone opposite Llanferres Church. The lowest beds are well exposed around the village of Cilcain, for although the country is all under cultivation, numerous small quarries, shown on the 6-in. Ordnance Map and

indicated by "Limekilns," expose the strata. Close to the road from Pont-newydd there is a quarry in light grey limestone which contains *Euomphalus pentangulatus*, fine specimens of *Productus cora*, *Syringopora geniculata*, and some doubtful corals, and is evidently the Middle White Limestone. On the south-east of the village there is a quarry in hard light brown limestone, which is divided by bedding planes without any interstratified shale, and represents the Lower Brown Limestone. It contains *Productus cora* and *Spirifera elliptica*, and there are some mineral veins and joints filled with Calcite and Arragonite. The veins run nearly north and south, while the limestone dips slightly to the east and is nearly at the base of the formation. At Llys-frynydd, a quarter of a mile to the south, there are several quarries in a similar light brown limestone, and in the central quarry it is of a sandy character. Although the limestone in these quarries about Cilcain contains less shale and is of a more massive character than the Lower Brown Limestone further south, it certainly belongs to that subdivision, and probably the sandy beds are limited to some of the lowest strata, where the limestone is thickest, and was deposited in the hollows of the old sea-bottom.

The Carboniferous Limestone at Cilcain is remarkable for the manner in which it extends up the rising ground to the west—covering the Wenlock Shale with a sheet of limestone, which ends with a thin edge. This creeping of the base of the limestone up the slope of the hills, opposite to where it is so fully developed, proves that it must originally have been much thicker and have extended much farther west than it does now. As the Carboniferous Limestone also occurs in the Vale of Clwyd, fringing the western base of the Moel Fammau range, it seems probable that these hills of Wenlock

Shale may have been originally covered by Carboniferous strata. The conditions are entirely different near Llangollen, where the Upper Grey Limestone overlaps all the lower subdivisions and rests directly on the Wenlock Shale, while in the country around Cilcain the whole of the subdivisions were deposited in regular succession, but have since been denuded, leaving only a thin remnant of the Lower Brown Limestone.

NANNERCH.

Proceeding northward, the Lower Brown Limestone is exposed in a quarry opposite the Railway Station, where about 50 feet of thin bedded light brown limestone is interstratified with a few thin seams of black shale, and dips 10° to the north-east. Near the bottom of the quarry there is a thin seam of shaley coal 4 inches thick, which some years ago was 6 inches, but the thickest portion has been removed by the quarrymen. In this quarry *Productus comoides*, *P. cora*, and *Spirifera lineata* occur. The Lower Brown Limestone is again exposed in a quarry on the roadside near Melin-y-wern, where the limestone is of a sandy character, but without partings of shale. There is a band of chert, 3 inches thick, near the bottom of the quarry, and the strata dip 10° to the north-east. *Productus cora*, *Spirifera lineata*, *Syringopora reticulata*, *Leperditia suborbiculata*, and obscure stems of plants occur, all species that are found in the same subdivision near Llangollen.

Still further north at Ysceifiog, close to the village, there are quarries in the Lower Brown Limestone, and again half way between that place and Caerwys, there are several large ones in the same subdivision, and as they are all worked on the top of the hill a thickness of at least 100 feet seems certain. Near Bron-fadog there

is a quarry in the Middle White Limestone where *Chonetes papilionacea, Productus cora,* and *Spirifera elliptica* occur. In all these quarries the dip of the strata is about 10° to the north, or north-east.

CAERWYS.

There are several quarries near the village of Caerwys. The Lower Brown Limestone is exposed in the farm-yard on the right of the road from the Railway Station to the village, where the limestone seems to be close to the base of the subdivision, though the underlying Wenlock Shale cannot be seen. The dip is 20° N., but no fossils were noticed. Nearer the village, at Marrion, the dip of the hard brown limestone is the same, and it contains fragments of *Euomphalus, Productus* and *Syringopora.* The limestone is exactly like the strata on the same horizon at Ysceifiog and Nannerch, so that along the ridge in this part of Flintshire the Lower Brown Limestone is continuous and of the same lithological character. The Middle White Limestone occurs on higher ground around the village, but is of a dark grey colour, and dips north-north-east. *Euomphalus* s.p., *Chonetes papilionacea, Productus cora, Spirifera elliptica, S. lineata, Syringopora geniculata,* and a species of *Cyathophyllum* occur. The Railway Station is about a mile from Caerwys, but as most of the quarries are on the road, a few hours afford sufficient time to examine the locality.

RHYD-Y-MWYN.

The Middle White Limestone is frequently exposed in the country to the north-west of Mold, and is of a uniform light grey colour, with very few fossils. There is a footpath from "The Loggerheads" by Pont-newydd to Rhyd-y-mwyn along the side of the dry channel of a

water-course, which was constructed to convey water for mining purposes to the latter place, about 50 years ago. It runs along the west of Cefn-mawr above the Alyn, through a rocky valley, and affords a fine view of the Middle White Limestone. Between "The Loggerheads" and Pont-newydd the cliffs of limestone are from 100 to 200 feet high along the strike of the strata, which usually dip at an angle of 15° south-east. The limestone is usually of a light grey colour, in beds from one to three feet in thickness, and often of a compact character like marble, but there are few fossils excepting *Productus cora*. Along this portion of the bed of the Alyn there are numerous open joints and many swallow-holes in the limestone, which absorb the water, so that in summer the bed of the stream is a mere series of shallow pools, or dry altogether, between the Glan Alun Mine, near "The Loggerheads," and a cliff of limestone half a mile north-east of Pont-newydd, where another mine is worked. At the Glan Alun Mine the whole of the water rushes down a swallow, so that the river is then only fed by a few tributary streams, which are absorbed one after the other until a considerable body of water flows from the base of the limestone cliff below Pont-newydd. There is a spring at the bottom of a talus and an adit level from which water rushes out. Very little water issues from the spring in summer, and in August, 1883, it was almost dry, but the supply from the mine is large and constant. It is very improbable that the whole of the water absorbed by the joints and swallows along the higher course of the Alyn finds its exit by the springs below Pont-newydd at the present time, though it may have been so when the country was in its natural condition, before any mines were worked in the district. Now there are many mines within a few miles from

the Alyn, and they are usually so flooded with water that they have been difficult to work for many years. It is probable that there is a connection between the joints and swallows along the bed of the Alyn and the lodes at a considerable distance from the river. The Glan Alun Mine is close to the river, and the late Capt. W. Roberts, who was connected with it, informed me that there was a direct communication between the swallows and the levels at a considerable depth. He also stated that after a heavy storm of rain the water descended into the workings in about 24 hours, and an examination of the exposed limestone intersected with open joints over the surface of Cefn-mawr, 100 or 200 feet above the Alyn, shows that much of the water must find its way from the ground above into the mine below, though the Alyn affords a more constant and larger supply.

Between the Glan Alun Mine and Pont-newydd the Alyn flows from south to north, but on reaching the latter it runs to the north-east, and as it crosses the strike of the beds there are cliffs, or rapidly rising ground on each side, until on reaching Rhyd-y-mwyn it begins a circuitous course to the Dee. The Middle White Limestone forms the cliff at the base of which the springs enter the Alyn, but at a higher level the Upper Grey Limestone succeeds and forms a belt of ground running north and south. The Arenaceous Limestone then follows in ascending order with a rapid easterly dip, and there are many exposures of it on both sides of the Alyn.

Between Gwern-y-mynydd and Rhyd-y-mwyn the Arenaceous Limestone is frequently exposed, particularly in some quarries at Pant-y-buarth and Waen, which is Trinity Church on the 1-inch Survey Map. A little west

of Waen the sandstone beds interstratified with the limestone crop out on the north of the road, and the Upper Grey Limestone occurs, in front of the "Crown Inn," while still more west the Middle White Limestone crops out, and is conspicuous on the surface as the ground descends to the Alyn.

One of the finest sections in Flintshire is exposed along the Hendre Valley, about a mile north of Rhyd-y-mwyn, where the railway and the road run through a gorge in the Carboniferous Limestone. The strata are quarried on both sides, but principally on the north, where the Upper Grey and Arenaceous Limestones are both seen in a continuous section. The strata were measured when with Mr. A. Strahan, F.G.S., as follows:

ARENACEOUS LIMESTONE AND UPPER GREY LIMESTONE,

HENDRE VALLEY, RHYD-Y-MWYN.

		FT.	IN.
Arenaceous Limestone.	White sandstone	11	0
	Thin bedded limestone	6	0
	Limestone with chert at the top	25	0
	Rubbly limestone	9	0
	Hard white limestone	14	0
	Sandy limestone	45	0
	Rubbly limestone and black shale	55	0
	Yellow sandstone	24	0
		189	0

		FT.	IN.
Upper Grey Limestone.	Thin bedded limestone and black shale	50	0
	Grey limestone....................	10	0
	Thin bedded grey limestone ...	66	0
	Black shale	7	0
	Thick bedded grey limestone...	74	0
	Black shale, not exposed, but obtained from a boring......	20	0
		227	0

It is probable that the upper portion of the Arenaceous Limestone is absent, being faulted against the Coal-measures, for it is only half the thickness of the subdivision at Gwern-y-mynydd. The Upper Grey Limestone is nearly all exposed, and presents the most complete section of it in the district. The foregoing section gives the thickness and lithological character of the strata, and the numerous fossils that occur are identical with those found on the same horizon in other localities. The following species were obtained from the 7-feet bed of black shale in about ten minutes, and no doubt a few hours in the quarries would considerably increase the list:—*Athyris ambigua*, *Orthis Mitchelina*, *O. resupinata*, *Productus giganteus*, *P. longispinus*, *P. semireticulatus*, *Spirifera bisulcata*, *Alveolites septosa*, *Lithostrotion irregulare*, and *Lonsdaleia floriformis*.

In addition to these subdivisions the Middle White Limestone is well exposed along the railway cutting about a mile further on, and the Lower Brown Limestone occurs at Nannerch in its typical form as already described. The subdivisions into which the Carboniferous Limestone is divided are so fully exposed between Rhyd-y-mwyn and Nannerch, that there is no other

locality where they may be examined in such a short time.

The rising ground to the north-east of Rhyd-y-mwyn is formed of Coal-measures, which are faulted against the Arenaceous Limestone, and on the plateau above the Rhos-esmore Mine is situated; but there is no exposure of the strata of consequence nearer than Moel-y-Gaer, 993·5 feet above ordnance level. On the summit there is an ancient British Entrenchment about 200 yards in diameter, from which a fine view of the surrounding country is obtained, especially of the Halkin mining district, in a north-westerly direction, dotted over with quarries and mines as far as the eye can reach. On the west side of Moel-y-Gaer, close to the top, the Lower Cefn-y-Fedw Sandstone occurs, about 20 feet of it being exposed in some small quarries. It is a fine grained white sandstone with quartz pebbles, which occur at intervals and in lines a few inches thick, as at Bryn gwyn, near Gwern-y-mynydd. The sandstone in some beds gradually becomes quartzite, and in others has been altered into chert. This alteration of sandstone into quartzite and chert may sometimes be seen within the space of a few inches. On the south-east of the hill there is an old quarry, where the Lower Cefn-y-Fedw Sandstone is again seen reposing on the top of the Arenaceous Limestone, as shown in the following section:—

		FT.	IN.
Lower beds of the Lower Cefn-y-Fedw Sandstone.	White cherty sandstone	15	0
	White and black shale	3	6
	Grey sandstone, with quartz pebbles at the top	3	6
		22	0

		FT.	IN.
Upper beds of the Arenaceous Limestone.	White and black shale	3	0
	Thin bedded grey limestone......	10	0
	Thick ,, ,, ,, ...	10	0
		23	0

The strata in this quarry as well as on the other side of the hill, dip 30° W.; but as the cherty sandstone at the top of the section is evidently the same as the beds exposed on the west of the hill, there must be a fault between. The lower part of the quarry is now partially filled up with *débris* from a shaft on one side of it, and *Productus giganteus*, *P. longispinus*, *Spirifera bisulcata*, *Alveolites septosa*, and *Lithostrotion irregulare*, were seen in the limestone and shale brought up.

About a mile to the north-west there is another conspicuous hill, Moel Ffagnallt, 833·6 feet high, remarkable on account of the arched form of the strata. The highest bed is a sandstone, which is 6 feet thick, and dips 30° to the west on that side of the hill; while on the east side it is 9 feet thick, and dips 32° to that direction. Under this sandstone, and forming the arch, or dome, there are about 40 feet of a light-grey limestone which belongs to the base of the Upper Black, or the top of the Upper Grey Limestone. The persistent character of the Lower Cefn-y-Fedw Sandstone and the sandstones associated with the Arenaceous Limestone has been described as occurring in the country to the south; but they end abruptly at Moel-y-Gaer and Moel Ffagnallt, and it is remarkable that there is no trace of them to the north of those hills. It does not seem that any fault cuts off the sandstones, for a little further north, about Halkin, the same subdivisions are exposed, without any interstratified sandstones, so that they must have thinned

out, while the limestone strata are continuous. The character of the deposits probably changed on account of some physical alteration in the area of which nothing is now known. It may have been caused by a change in the direction of the currents at the time the strata were being deposited; for such alterations in the nature of the bed of the sea are well known, and sometimes there are sedimentary changes along coast lines for which it is difficult to account.

HOLYWELL.

In the country around Holywell the Cherty Shale, in the absence of the Lower Cefn-y-Fedw Sandstone, rests directly on a subdivision of black limestone, some beds of which are called the Aberdo limestone, and worked for the manufacture of cement. From its position and fossils it is evident that this black limestone, with its associated shales, is the continuation northward of the Arenaceous Limestone, after the sandstone beds interstratified with it more south have thinned away. But, as the name of the subdivision seems inapplicable in the north of Flintshire, I propose to call it the Upper Black Limestone, and to consider it as the top of the Carboniferous Limestone. It will be convenient here to give the general succession of the Carboniferous Limestone and Cefn-y-Fedw Sandstone as they are presented under a different aspect in the north of Flintshire compared to the south of the county as given at a former page.

SUBDIVISIONS OF THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF THE NORTH OF FLINTSHIRE.

CARBONIFEROUS SANDSTONE.

Subdivision.	Thickness in feet.	Locality where well exposed.
Gwespyr Sandstone	120	Gwespyr and Ffynnongroew.

Subdivision.	Thickness in feet.	Locality where well exposed.
Cherty Sandstone	250	Halkyn, Pentre Halkin, and Gronant.

CARBONIFEROUS LIMESTONE.

Subdivision.	Thickness in feet.	Locality where well exposed.
Upper Black Limestone	200	Pen - y - ball, Holywell Common, and Prestatyn.
Upper Grey Limestone	150	Halkin and Gwaenysgor.
Middle White Limestone	600	Crecas, near Holywell, Newmarket.
Lower Brown Limestone	200	Nannerch, Caerwys, and Moel Hiraddug.
	1,520	

In the country about Holywell and Halkin the Carboniferous Limestone is traversed by so many faults that the exact correlation and succession of the strata is often uncertain; and the determination of the thickness of the subdivisions only estimated by that actually seen and by general observations over a large area. The Lower Brown Limestone at Nannerch and Caerwys has already been described, and the Middle White Limestone is worked in two large quarries at Crecas, near Pantasa, and it occurs along a broad belt of cultivated ground between Holywell and Caerwys. The Upper Grey Limestone succeeds in ascending order, followed by the Upper Black Limestone, with the Cherty Sandstone, the lowest subdivision of the Cefn-y-Fedw Sandstone, resting upon it, and the junction of the two latter subdivisions may frequently be seen. There is a gradual change from the highest beds of the Upper Black Limestone to those of the Cherty Sandstone, which is succeeded by the Gwespyr, or Ffynnon-groew Sandstone, while higher in the series the Holywell Shale representing the Lower Coal-measures is followed by the Productive Coal-measures.

MIDDLE WHITE LIMESTONE.

Having given the general succession of the subdivisions at Holywell, a more minute description may be given, with the exception of the Lower Brown Limestone, which has already been described. The Middle White Limestone may be easily examined at Crecas, where the limestone occurs in thick beds of a uniform white colour. Few if any fossils occur in it, so that it would require considerable time and patience to make a list from the specimens that might be found in it, and this paucity of fossils is so general with strata of this subdivision as to account for so few being recorded. The Middle White Limestone is not so well exposed anywhere else near Holywell, and the quarries at Crecas are of additional interest from the base of the Upper Grey Limestone being exposed at the top of the limestone. The line of separation is the thin bed of black shale shown in the following section of the strata in the east quarry, for in the one further west there is little, or no shale between the subdivisions, though the difference between them is scarcely less discernable.

		FT.	IN.
	Broken limestone and drift	10	0
Base of Upper Grey Limestone.	Thin bedded grey limestone......	10	0
	Black shale..........................	0	6
Upper beds of Middle White Limestone.	Thick bedded white limestone ...	45	0

UPPER GREY LIMESTONE.

About 50 feet of the Upper Grey Limestone are exposed in another quarry, on the tramway, a little to the east, where the limestone is of a light grey, which

weathers to white, and is near the base of the sub-division. Fossils are numerous, and include *Productus cora, P. giganteus, P. latissimus, P. semireticulatus,* and others. The Upper Grey Limestone, however, is not well exposed on Pen-y-ball, the hill above Holywell, but occurs further south near Halkin, where there is a fine section of it at the Halkin Limestone Quarry, and about 106 feet exposed, with the upper beds of the Middle White Limestone below it, and the dip is 16° to the south-east.

UPPER GREY LIMESTONE, HALKIN.

		FT.	IN.
Upper Grey Limestone.	Grey limestone, with thin nodules of chert	15	0
	Sandy grey limestone	8	0
	Grey limestone, with *encrinites*	8	0
	Sandy limestone	5	0
	Thin bedded grey limestone, top of quarry	23	0
	Grey limestone	5	0
	Thin bedded grey limestone	5	0
	Black shale, with ferruginous stains	1	0
	Grey limestone, used for gate posts, &c.	5	6
	Thin bedded grey limestone	31	6
		107	0
Upper beds of the Middle White Limestone.	Thick bedded white limestone	50	0

The usual fossils occur in the Upper Grey Limestone, and a fine specimen of *Orthoceras giganteum* about four

feet in length was found, a few years ago, just about the top of the lowest "Thin bedded grey limestone." The quarry is worked by Mr. Thomas Davies, who showed me the position in which the *Orthoceras* was found, and measured the 69 feet in the precipitous wall of the quarry, the higher beds being on the top of the hill.

The highest beds of the Upper Grey Limestone in Denbighshire and the south of Flintshire form a regular coral reef, but in the country about Holywell the numerous faults render it difficult to examine the beds on any particular horizon for a great distance, and the upper beds of the subdivision are seldom exposed. There is, however, a quarry a quarter of a mile south-east of Brynford, where the top of the Upper Grey Limestone is exposed, and the coral beds extend for about 50 yards from north to south. With the exception of a single specimen of *Lithostrotion basaltiforme*, a rare species in North Wales, all the others are large branching masses of *L. irregulare*, and seem limited to a thickness of two or three feet, by no means conspicuous, for the limestone is hard, and the corals do not weather out as they usually do in other localities that have been previously described. In several places on the hill-side below the quarry with the coral beds, and about 50 feet under them, some beds of encrinital limestone crop out, with a visible thickness of 7 feet. These encrinite beds seem limited to a particular horizon, though many other beds of limestone contain scattered stems, and are to be seen most fully exposed in some quarries one mile west of Pentre Halkin and about half that distance south of Pant-y-pydew. In one of these quarries the encrinite beds are 16 feet thick, but in another they are only 10 feet, and evidently vary in different places. Near the top of the section at the Halkin Limestone Quarry the thickness is 8 feet, and

there is a small quarry at Pen-y-ball top, only half a mile from Holywell, where 6 feet of encrinital limestone is visible, and seems to be in the Upper Grey Limestone near where it is faulted against the Upper Black Limestone. If the encrinite limestone is always on the same horizon, it affords a valuable datum for ascertaining the thickness of the beds belonging to the Upper Grey Limestone above those exposed in the Halkin Limestone Quarry, and an additional 30 feet would complete the subdivision.

UPPER BLACK LIMESTONE.

The next subdivision in ascending order is the Upper Black Limestone, which is well exposed in many quarry sections on Pen-y-ball, and represents the Arenaceous Limestone of the south of Flintshire. It consists of thin beds of black limestone with partings of shale, and some of the former are known as the "Aberdo Limestone," which is used in the manufacture of hydraulic cement. The following gives the section of strata exposed at Grange, north-west of Holywell:—

		FT.	IN.
	Made ground	10	0
	Drift	10	0
Middle beds of the Upper Black Limestone.	Thin bedded black limestone, with 2 or 3 thicker beds near the bottom	23	0
	Black shale	0	6*
	Solid grey limestone	9	0
	Thin limestone, Aberdo, in thin beds	14	0
		46	6

The Aberdo limestone has been worked on the dip for about 50 yards, when a downthrow fault brings in the

overlying Cherty Sandstone. Interstratified with the black limestone, containing few fossils, are several thick beds of grey or brown limestone, crowded with *Productus giganteus*, which are rejected by the limeburners and used for rough building purposes. Large blocks of this grey limestone may be seen lying about the surface of the ground, and at Clwt Militia they are placed in succession so as to form a wall along the edge of the quarries, which present the following section:—

		FT.	IN.
Middle beds of the Upper Black Limestone.	Grey limestone	3	0
	,, ,,	4	0
	Thin bedded black limestone	12	0
	Black shale	2	0*
	Grey limestone	5	0
	Thin bedded black limestone	25	0
		51	0

The quarries at Clwt Militia extend for above a quarter of a mile; the same beds are worked along the whole of them, and the strata dip about 5° to the north-east.

These two sections, however, only show a small portion of the Upper Black Limestone, as it is more fully exposed at Pant-y-pydew, a mile and a half to the south-east, as shown in the following section:—

		FT.	IN.
	Drift and broken rock	14	0
Middle beds of the Upper Black Limestone.	Grey limestone	7	0
	Thin bedded black limestone	9	0
	Black shale	0	9*
	Grey limestone, 3 or 4 beds	12	0
	Thin bedded black limestone	20	0
	Thin ,, ,, ,,	20	0
		68	9

Although the strata in the different quarries vary in detail, there is a close general resemblance between them. There are numerous thin partings of shale between the beds, and the black limestone weathers to a brown colour. The shale marked with an asterisk is on the same horizon in each section, and it is from the strata below the 9-feet bed that the limestone for making cement at Grange was obtained; so that it indicates the underlying position of the Aberdo limestone. The composition of this black limestone seems to vary, and whether that at Grange was the best for the purpose, or whether it was obtained there because it was the nearest to Holywell is uncertain, but it has not been worked underground in the same manner anywhere else.

The highest beds of the Upper Black Limestone consist of a series of dark grey beds, which may be examined in several places, and form the top of the Carboniferous Limestone. They are most fully exposed in a quarry a few hundred yards to the east of Brynford, where about 40 feet of thick bedded limestone occur, which dips 7° to the north-east and weathers to white, but when recently broken varies from light and dark grey to brown and black. It contains *Productus giganteus* and *P. fimbriatus*, and there are some concretions of chert in the beds near the top of the quarry. Strata on the same horizon again occur on the hill above the large quarries at Pant-y-pydew, where the solid dark grey limestone is made into gate-posts and tomb-stones, in a little quarry quite on the top and close to the outcrop of the overlying Cherty Sandstone. The following is a section of the whole of the Upper Black Limestone exposed at Pant-y-pydew, and it is the most complete exposure of the strata in the district, though the lowest beds of the subdivision are not exposed.

UPPER BLACK LIMESONE, PANT-Y-PYDEW.

		FT.	IN.
Upper Black Limestone.	Thin beds of limestone and chert	4	0
	Thin bedded limestone and chert, in nodular bands	9	0
	Thick bedded grey limestone, used for gate-posts............	20	0
	Limestone, not well exposed ...	25	0
	Thin bedded black limestone ...	30	0
	Black shale............................	1	0*
	Grey limestone	10	0
	Thin bedded black limestone, base not visible	60	0
		159	0

Interstratified with both the 30-feet and 60-feet of black limestone there are local grey limestones, but they are not so persistent as the "Grey limestone, 10 feet," though all abound with large specimens of *Productus giganteus*.

At Pant-y-pydew there are two instances of denuded surfaces, but they only extend over very limited areas and are more properly examples of false-bedding. The highest of these is along the bottom of the "Thin bedded limestone and chert in nodular bands," which rests on the denuded surface of the underlying "Thick bedded grey limestone used for gate-posts." The other and lower example is more remarkable and extends over a greater area, being perhaps 100 yards across, where it seems that the surface of the lower "Thin bedded black limestone" was worn into a channel, or gully, before the overlying bed of "Grey limestone" was formed over it. It is from the shale partings between the upper portion of the 60-feet of "Thin bedded black limestone,"

that the species of Polyzoa recently described by Mr. G. W. Shrubsole, F.G.S., of Chester, were obtained, and of which *Fenestella plebeia* is the more numerous, but *Serpulites carbonarius* and other fossils occur in the same beds. I found them when with Mr. John Aitken, F.G.S., about 14 years ago; they crowded the shale then, and have been collected ever since.

CEFN-Y-FEDW SANDSTONE.

CHERTY SANDSTONE.

The Cherty Sandstone, or Lower Cefn-y-Fedw Sandstone, is the next subdivision in ascending order, and is composed of a series of strata of chert, sandstone, and shale, but principally chert. Originally the strata were formed of sandstone, some of which is very fine grained with subordinate bands of shale. The sandstone has been for the most part converted into chert, but many beds are of an intermediate character and some are quartzite. Most of the chert is white, but some of it is black, while the shale is usually white, stained by iron-oxide. The chert is extensively worked near Pentre Halkin, and has been for above a hundred years. Pennant states that in his time it was quarried and sent to the Potteries, and it is still sent there, being used in the construction of grinding floors. About Halkin many of the shafts of the lead mines pass through the Cherty Sandstone with the Upper Black Limestone below, so that chert is to be seen strewn over a considerable area. The thickness of the Cherty Sandstone exposed along the outcrop is about 100 feet, but it is probably about 250 feet altogether. At Pentre Halkin the white shale, interstratified with the chert, contains *Chonetes Hardrensis* and *Productus longispinus*, and sometimes the chert contains fossils.

The Cherty Sandstone crops out along the country to the north-west of Holywell, but is not much exposed nearer than Gronant, near Prestatyn, where it often appears on the surface, and is extensively worked in a large quarry. The strata exposed are about 100 feet in thickness, and dip 15° to the north-east. The chert beds vary from a few inches to a foot in thickness, and are of a dark brown or black colour. The top and bottom of each bed is a hard fine grained brown sandstone, and only the centre is chert, which sometimes resembles flint, and occasionally in hand specimens a bluish opal. The partings between the strata are merely bedding planes, for there is little or no shale between them, and the beds are remarkably alike throughout.

The shaft of the Talacre and Gronant Mine at Gronant, Capt. H. Ellis informed me, is 312 feet deep, and entirely in the chert to the depth of 300 feet. Below the chert there are beds of shale, limestone, and a white calcareous sandstone, evidently the top of the Upper Black Limestone. This shaft affords the most reliable measurement of the Cherty Sandstone, in the north of Flintshire, and, allowing for the dip, 250 feet is the thickness it is assumed to be.

GWESPYR SANDSTONE.

The Cherty Sandstone is succeeded by the Gwespyr Sandstone, which represents the Upper Cefn-y-Fedw Sandstone. Little is seen of this subdivision about Holywell, though the base of it occurs near Highbrook and Eyton's Shaft, places within a mile north-west of the town. In both there is a section of 20 or 30 feet of yellow sandstone, evidently just over the Cherty Sandstone, and I am indebted to Mr. J. J. Williams, C.E., F.G.S., for pointing it out to me. It is, however, around the village of Gwespyr, about three miles west of

Prestatyn, that the sandstone so named may be seen exposed in its full development, in about six quarries worked along the strike of the beds. The sandstone is a thick bedded rock of a greenish grey colour, extensively used for architectural purposes, as in the new church at Prestatyn. There are two beds of shale about the middle of it; they occur in most of the quarries, and the sandstone usually dips about 10° W. or W.S.W., but varies, and is only 5° W.N.W. in the quarry to the north of the others. On the Mostyn Estate the Gwespyr Sandstone is worked, and it must have been for many years, for near the Hall there is a large quarry where ivy covers the rocky cliff and trees have grown around, giving a romantic aspect to the spot. The following shows the strata exposed in the north quarry referred to:—

		FT.	IN.
Gwespyr Sandstone.	Grey sandstone	25	0
	Shale	2	0
	Grey sandstone	10	0
	Shale	2	0
	Grey sandstone	50	0
		89	0

In the quarry now worked in the Park there are some remarkable concretions of sandstone, about three or four feet in diameter, associated with the lowest visible beds. They are more or less spherical, some are egg shaped, and others of an irregular form. Where the sandstone has been removed these concretionary nodules have been left in the quarry, and are interesting objects to all who see them. I estimated the thickness of the Gwespyr Sandstone to be 100 feet, but afterwards, when with Mr. C. E. de Rance, F.G.S., we thought 120 feet might be a nearer approximation.

NOTES ON THE CARBONIFEROUS LIMESTONE OF BELGIUM, MADE DURING A RECENT VISIT TO THAT COUNTRY.

By G. H. Morton, F.G.S.

ABSTRACT.

The Carboniferous Limestone is well developed in Belgium, and there are three localities where it may be seen to advantage and the fossils collected. These are Visé, near Liége, Waulsort, near Dinant, and Tournay, in the west of Belgium.

At Visé the upper beds of the *calcaire carbonifère* are well exposed in a series of quarries along the east side of the River Meuse, and are succeeded by the *systeme houiller sans houiller*, represented by thick beds of shale. The limestone is of a grey colour, and is remarkable for the great number of fossils it contains, though it is so hard that it is difficult to obtain good specimens. There are many to be obtained where the rock has weathered, and *Euomphalus acutus*, *Productus cora*, *P. punctatus*, *P. semireticulatus*, *Spirifera glabra*, *S. lineata*, and *S. pinguis* are some of the most frequent. Between the limestone and the overlying shale there is about four feet of black chert.

At Waulsort, a few miles south of Dinant, the middle beds of the Carboniferous Limestone are exposed in a precipitous cliff along the railway, half a mile to the east of the station, at a place known as Les Pauquis, where the limestone is thick bedded and of a light grey colour. *Euomphalus pentangulatus*, *Spirifera bisculata*, *S. Mosguensis*, and *S. striata* were collected, and many

other species might be obtained by breaking up the fragments of limestone which form a talus on the side of the cliff.

At Tournay the lowest beds of the Carboniferous Limestone are exposed in some large quarries on the south-east of the town. The limestone is black and thin bedded with *Productus punctatus* and several corals, including *Syringopora*. It is used as flags in many towns in Belgium, and the pavements along the streets of Brussels, particularly when wet, exhibit beautiful sections of Gasteropods and corals.

Each of these localities has yielded a great number of fossils, and lists containing most of the species are given in Dewalque's "Geology of Belgium," 2nd Edition, 1880, but Prof. L. G. de Koninck has added many new species since. Many of the specimens found at Tournay are remarkably perfect, such as *Orthoceras canaliculatum*, *Nautilus Konincki*, *Pleurotomaria Yvani*, and *Euomphalus crateriformis*, and others.

The Carboniferous Limestone is well exposed along the banks of the Meuse, from Liége south-west to Huy and Namur. The strata are often vertical for considerable distances, and as some of the beds have been denuded, while others project in rib-like masses, very beautiful scenery is produced, unlike that of the same formation in England or Wales. Where the strata are less inclined, the river valley resembles that of the Avon at Clifton, though on a grander scale, for the cliffs along the Meuse extend such a great distance, and present an ever varying precipitous limestone escarpment. The river valley is usually less than a quarter of a mile wide, and the river, the railway, and a good road run along side by side. With the rocky precipitous cliffs always in view, the country appears to be of a hilly character, while

in reality it is very flat, for on ascending the cliff a tame uninteresting country is seen stretching away as far as the eye can reach. The vertical limestone at Dinant has a fortress on the top commanding the town, from which a magnificent view is obtained of the valley of the Meuse, and the mind is naturally led to reflect on the enormous time that the river has flowed along to deepen its channel about 200 feet.

DESCRIPTION OF A GEOLOGICAL MAP OF THE STORETON QUARRIES, CHESHIRE.

By G. H. Morton, F.G.S.

ABSTRACT.

The Map exhibited is a portion of the 25-inch Ordnance Map, geologically coloured to show the Upper Mottled Sandstone, Keuper Sandstone, and Red Marl, over an area of about half a mile, the Map being 22 inches in diameter. Few localities show so many faults in such a limited area, for 22 are shown on the Map, and the places where they are exposed are indicated by an asterisk. Of these faults 17 run nearly north and south, and only 5 run east and west. Although the faults on the Map are continued for various distances, it is impossible always to prove the exact direction, or even the continuity, of some of them, but great care has been taken to obtain the true bearings; and though some of the lines may hereafter require correction, the Map as exhibited conveys a correct idea of the complicated dislocations that have taken place. The great length of the north and south faults, compared with those running

east and west, is remarkable, and the enormous pressure indicated by the long slips of sandstone that have been cut so near together by the long parallel fractures. Another source of interest in connection with the faults is the upthrow of the strata, about 100 feet, to the north by an inferred fault running east and west, just north of the National School. This fault has not been exposed, but is laid down in order to account for the appearance of the *footprint bed* at the surface, a few hundred yards to the north, where, in the absence of such a fault, it would be at a considerable depth beneath the surface. There is, however, an east and west fault visible in an old quarry, just south of the road which runs east and west, but it is a small downthrow to the north and throws the *footprint bed* down, instead of up to the north. Consequently, to account for the upthrow of the strata 100 feet it is necessary to infer the existence of the fault described.

The thickness of the Keuper Sandstone in the Storeton Quarries is about 208 feet, the highest beds being just over the *footprint bed* and faulted against the Red Marl. The upper beds of the Keuper Sandstone have been denuded at Storeton, and those that remain are only about half the thickness of the formation at Liverpool. Since the publication of "The Geology of the Country Around Liverpool," in 1863, a basement bed of 60 feet has been proved, below the Keuper described and shown in a section of the strata at the Storeton Quarries in that work. The Red Marl formation has also been discovered since that year, but it is only exposed in one of the northern quarries. Future excavations may add additional interest to the petrology of the Storeton Quarries, but if appropriated for building purposes little, if any, more information will be obtainable.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D.Sc., Queen's College, Galway.
JOHN W. JUDD, F.R.S., F.G.S., London.
ARCHIBALD GEIKIE, D.Sc., F.R.S.

MEMBERS.

*ARCHER, F., B.A., Boundary Cottage, Crosby.
14, Cook Street.
*†BEASLEY, H. C., Prince Alfred Road, Wavertree.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
*BROWN, J. CAMPBELL, D.Sc., F.C.S., 27, Abercromby Square.
DAVIES, C., 8, Kinglake Street, Edge Hill.
DODD, J., 2, Derby Terrace, Rock Ferry.
*†ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackin's Hey.
FITZPATRICK, M., 62, Seel Street.
FITZPATRICK, J. J., 62, Seel Street.
†FOSTER, E., 7, Newstead Road, Smithdown Road.
GREEN, A., York House, Old Chester Road, Rock Ferry.
9, Canning Place.
GRIFFITHS, J., 4, Exton Park, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B. (Hon. Treasurer), Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
HERDMAN, W. A., Prof., D.Sc., F.L.S., F.R.S.E., University College.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W., B.Sc., 21, Verulam St., Upper Parliament St.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport.
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
LEA, T., Vale Cottage, Huyton Quarry.
LEIGH-GREGSON, S., Aigburth Road.
Slater Court, 5, Castle Street.

*MACKINTOSH, D., F.G.S., 32, Glover St., Borough Road, Birkenhead.
*McCLAY, J. L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MAYER, J., F.S.A., Pennant House, Lower Bebington.
MANSELL, Rev. J., 10, Kremlin Drive, Stoneycroft.
*MOORE, T. J., C.M.Z.S.L., Newsham Drive, Newsham Park.
Liverpool Museum.
*MORGAN, A., 3, Aughton Road, Birkdale.
10, St. George's Crescent.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I. (Hon. Secretary), 4, Onslow Rd., Elm Park. 122, London Road.
†MOTT, C. G., Sunnyside, Cavendish Road, Birkenhead.
McMILLAN, A., Conway, North Wales.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PEARSE, W., 21, Harrington Street.
Green Bank Farm, Wavertree.
*†PICTON, Sir J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
PEARSON, J. E., Golborne Park, near Newton-le-Willows.
QUILLIAM, W. H., 30, Rufford Road, Fairfield.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Valley Lodge, Borough Road, Birkenhead.
ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
STONE, R., Jun., Newton Park, Newton-le-Willows.
STRONGITHARM, G., 77, Whetstone Lane, Tranmere.
SPARGO, E., Bangor, North Wales.
SHERLOCK, C., 63, South John Street.
*TATE, G., Ph.D., F.G.S., F.C.S., Liverpool College of Chemistry, 96A, Duke Street.
THOMAS, H., 21, Kinglake Street.
TIMMINS, A., C.E., Mill House, Runcorn.
WILSON, W. H., St. Michael's Hamlet, Aigburth.
31, Wapping.
WRIGHT, B. M., F.R. Hist. Soc., 204, Regent Street, London.
*WARD, T., Northwich, Cheshire.
YOUNG, H., 12, South Castle Street.

ASSOCIATES.

MORGAN, Mrs., 3, Aughton Road, Birkdale.
MORTON, Miss S. E., 4, Onslow Road, Elm Park.
ROBERTS, Mrs., Kennessee, Maghull, Lancashire.
READE, Mrs., Park Corner, Blundellsands.

---

* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-FIFTH,

1883-4.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART VI.—VOL. IV.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1884.

OFFICERS, 1883–84.

President.

T. MELLARD READE, C.E., F.G.S.,

Vice-President.

CHARLES RICKETTS, M.D., F.G.S.

Ex-President.

DANIEL MACKINTOSH, F.G.S.

Honorary Treasurer.

EDWARD W. HANCE, LL.B.

Honorary Librarian.

EDWIN FOSTER.

Honorary Secretary.

GEORGE H. MORTON, F.G.S., F.R.G.S.I.

Council.

WILLIAM A. HERDMAN, D.Sc., F.L.S., F.R.S.E.
ARTHUR TIMMINS, C.E.
HENRY C. BEASLEY
ISAAC ROBERTS, F.G.S.
GEORGE TATE, Ph.D., F.G.S., F.C.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

Advocates' Library, Edinburgh.
Belfast Naturalists' Field Club.
Birkenhead Free Public Library.
  Do. Literary and Scientific Society.
British Museum.
Bristol Naturalists' Society.
Bodleian Library, Oxford.
Boston Society of Natural History, U.S.
Chester Society of Natural Science.
Dudley and Midland Geological and Scientific Society.
Epping Forest and County of Essex Naturalists' Field Club.
Editor of "Geological Record."
  ,, "Nature."
  ,, "Geological Magazine."
  ,, "Science Gossip."
  ,, "Science Monthly."
Ertborn, Le Baron O. Van, Anvers, Belgique.
Geological Society of Edinburgh.
Geological Society of Glasgow.
Geological Survey of India.
Geological Society of London.
Geological Society of Manchester.
Geological Survey of the United States.
Geological and Polytechnic Society of the West Riding of Yorkshire, Leeds.
Geologists' Association, London.
Glasgow Philosophical Society.
Hayden, Dr., United States.

Koninck, L. G. de., Prof., Liege.
Leeds Philosophical and Literary Society.
Liverpool Athenæum.
,, Chemists' Association.
,, Free Public Library.
,, Geological Association.
,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
,, Polytechnic Society.
L'Universite Royal dè Norvége, Christiana.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal D'Histoire Naturelle de Belgique.
Museum of Practical Geology, Jermyn Street, London.
North of England Institute of Mining and Mechanical Engineers.
Orleans County Society of Natural Science, Vermont, U.S.
Owens College, Manchester.
Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
Smithsonian Institution, Washington, U.S.
Société Geologique de Belgique, Liege.
Société Geologique du Nord, Lille.
Toscana Societa di Scienza Naturali.
University Library, Cambridge.
Warwickshire Natural History and Archæological Society, Warwick.
Watford Natural History Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-FIFTH.

OCTOBER 9TH, 1883.

THE PRESIDENT, DANIEL MACKINTOSH, F.G.S., in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been audited by Dr. HERDMAN and Mr. T. MELLARD READE.

The PRESIDENT then read his Annual Address:—

THE TIME WHICH HAS ELAPSED SINCE THE CLOSE OF THE GLACIAL PERIOD.

NOVEMBER 13TH, 1883.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The Rev. FRANK BALLARD, M.A., was elected an Associate.

The following paper was read:—

SECTION ACROSS THE TRIAS RECENTLY EXPOSED IN A RAILWAY EXCAVATION IN LIVERPOOL.

By G. H. Morton, F.G.S.

DECEMBER 11th, 1883.

The President, T. MELLARD READE, C.E., F.G.S., in the Chair.

J. C. Parkinson and Osmund W. Jeffs were elected Ordinary Members.

The following paper was read:—

THE DENUDING INFLUENCE OF SEA-CURRENTS, RIVERS, RAIN, AND ICE; WITH REMARKS ON THE ORIGIN OF TABLE-LANDS, ESCARPMENTS, AND VALLEYS.

By D. Mackintosh, F.G.S.

JANUARY 8th, 1884.

The President, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following paper was read:—

EXPERIMENTS ON THE CIRCULATION OF WATER IN SANDSTONE.

By T. Mellard Reade, C.E., F.G.S.

FEBRUARY 12TH, 1884.

The REV. JOHN MANSELL in the Chair.

The following papers were read :—

ON INDENTED PEBBLES.

By C. RICKETTS, M.D., F.G.S.

THE CARBONIFEROUS LIMESTONE OF THE NORTH OF FLINTSHIRE.

By G. H. MORTON, F.G.S.

MARCH 11TH, 1884.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

Mr. WILLIAM WISE exhibited a section recently obtained while boring for water at Birkenhead.

The following paper was read :—

ESTIMATES OF TIME IN REGARD TO CAVE DEPOSITS.

By REV. FRANK BALLARD, M.A.

PRESIDENT'S ADDRESS.

THE TIME WHICH HAS ELAPSED SINCE THE CLOSE OF THE GLACIAL PERIOD.

By D. Mackintosh, F.G.S.

I. *Introductory Remarks.*—At the commencement I ought to state that a small part of the subject of this paper was discussed last February, at a meeting of the Geological Society of London, when some of the speakers appeared to lay too much stress on long periods of time. In case it should be suspected that I am biassed in favour of short periods of time, I may state that about forty years ago I wrote a book, the main object of which was to shew that a geological theory (*cœteris paribus*) is probable in proportion to the length of time it involves. This work was recommended for publication by one of the most eminent geologists then living to one of the most eminent publishers, who (for reasons which it is unnecessary to state) did not see his way clear to undertake its publication.

II. *Brief Statement of the order of Glacial Events.*—Those British and American geologists who have made the most extensive observations, are now very nearly agreed in believing that there was—*first*, a period of land-ice which filled up the valleys, and covered many of the mountains; *second*, a submergence of the land which commenced *before* the close of the land-ice period,

continued during a comparatively mild period, and did not terminate until *after* the commencement of a second period of land-ice.

III. *Condensed Statement of Professor James Geikie's Discoveries and Opinions.*—Striated rock-surfaces are found on certain parts of the sea-coast of Scotland, where they lie lower than the latest *post-glacial* "raised beaches" which more or less cover the glaciated rocks. Below the level of the raised beaches the sea (when the beaches were deposited) covered and protected the glaciated rocks. The sea was then 20 to 30 feet higher than now. Around the sea-lochs of the western Highlands and Sutherland, and likewise on the east coast, glaciers came down to the sea-level (when it was 20 to 30 feet higher than now) in Neolithic times. The epoch of the latest glaciers in Scotland was separated from the last great glacial period by the oldest submarine forests, and the buried trees at the bottom of peat bogs. Then the land went partially down, and the latest (now) raised beach was deposited. Glaciers again appeared in the mountain valleys and came down to the sea-level. Neolithic man was then living, since we find his canoes lying at the bottom of the Carse-clays, associated with the trees of the submarine forests. To this statement of Professor James Geikie's discoveries, I may add that Mr. Kinahan has found traces of the continuance of local glaciers in Ireland so late as the time when the 300 feet and 100 feet raised beaches were formed.

IV. *Time indicated by the fresh appearance of Roches Moutonnées and glaciated Rock-surfaces.*—In the north and west-central parts of Wales the smooth curvilinearity of many roches moutonnées has been preserved to a remarkable extent, notwithstanding their exposure to atmospheric action. In the Pass of Nant Francon,

towards the lower end, and nearly opposite to the slate quarries, there are many well-defined, but little noticed *roches moutonneés*, which (though in a moist district) have retained their smoothness to a striking extent. Between Cwm Croesor and Beddgellert there are numerous large roches moutonnées which retain more or less of their polish; and at a height of more than 1,800 feet above the sea, on the south side of Bwlch-cwm-Orthin, I found many smoothed rock-surfaces with well preserved striæ. In many parts of Cumberland where there is little appearance of the glaciated rocks having ever been preserved by drift from atmospheric action, they are still so smooth that a person heedlessly walking over them might very soon experience an undesirable downfall; and this is even the case where the rocks are of a felspathic or porphyritic character, and thereby liable to become roughened by chemical as well as mechanical disintegration. Between Stickle Tarn and Easedale, a large roche moutonnée rises out of a peat bog, where there is no appearance of its ever having been protected by drift from atmospheric action, and yet I could detect on its surface a few fine striæ which had resisted the action of rain and frost since it became exposed to the weather, through the melting of the ice by which it had been formed. The extremely fresh appearance of many moraines may likewise be regarded as an evidence of the recent close of the glacial period.

V. *Time indicated by the Pedestals of Boulders.*—On grass or heath-covered surfaces around Llangollen there are many boulders of Arenig or Aran felsite, on the leeward side of which there is a hollow excavated by wind-blown rain, while splashing down from the boulder. The average depth of such hollows is not more than about six inches.

About two and a-half miles north of Llangollen, a ravine above Brook House leads up to a high limestone plateau on the left, called Craig-yr-ogof. On then going north towards a ravine called Nant-hen-Gastell, many boulders of Arenig felsite may be seen on grass, fern, or heath-covered surfaces, with a hollow on one or two sides caused by the down splashing of concentrated rain-water from the boulders. After crossing this ravine, and turning to the left as far as the brink of the innermost well-defined cliff-line, a monstrous-looking boulder, of nearly black felsite, about 8 by 7 by 5 feet in diameter, may be seen in a perched position, close to the brink. It has a rather irregular fragmentary pedestal of limestone, from eight to nine inches in average height above the surrounding ground; but it is possible it may have found this pedestal ready-made, so that it can admit of no reliable calculations concerning the time required for the circumjacent denudation of the limestone rock. Farther north, a small boulder may be seen resting partly on limestone, with a surface around the boulder which has been lowered only about two inches by rain, since the boulder came into its present position. On the neighbouring limestone outcrops, other boulders may be seen, around which the action of rain has lowered the general surface to the extent of only a few inches. From a comparison of facts, and after rejecting boulders which may have found ready-made pedestals, I have been led to the conclusion, that if we include hollows (chiefly on the leeward, but likewise on the windward side of boulders, and to a small extent all round the boulders), the average vertical extent of circumjacent denudation since the boulders were left by melting ice, has not been *more* than about six inches, and that this extent does not necessarily indicate a period of more

than a few thousand years (see sequel). Before leaving this plateau, it may be well to state that many of the boulders show signs of having fallen from a great height (probably from floating ice), for the boulders have not only been fractured, but the limestone rocks on which they fell have been rent and shattered to a very striking extent. It ought not to be forgotten that *many* of the boulders would appear to have fallen on bare limestone rock, as there are no traces of drift or Boulder-clay around or under them, so that the circumjacent denudation of the limestone may have commenced immediately after the fall of the boulders. The absence of Boulder-clay may be readily explained by the inability of submarine currents to transport it in an easterly direction across deep valleys and steep ridges, and finally up the steep and (in many places) over-hanging face of the Eglwyseg Cliffs.*

VI. *Boulders on Limestone Rock-surfaces near Clapham, Yorkshire.*—After walking about a mile and a-half along Thwaite Lane, east of Clapham, and crossing one or more walls in a northerly direction, one arrives at the base of a steep limestone escarpment. On rounding the east end of this escarpment and walking up a stone-covered slope on the left, the lower part of the great limestone plateau, marked Norber on the Ordnance maps, suddenly comes into sight. It cannot fail to be noticed that the surfaces of the limestone rocks are often flat, and terminate in miniature cliffs with steep

* Near the centre of Halkin Mountain (Flintshire), and close to a place called Trama Cottage, there are numerous large boulders on limestone rocks, but their bases are too much concealed by creeping vegetation to admit of reliable observations being made to determine the height of the supports of the boulders above the surrounding rock-surfaces.

brinks, as if whole blocks or fragments of rock had been removed by land-ice, floating ice, or according to Professor Phillips, by powerful currents. Partly resting on fragmentary rocks, and partly on flat and extensive rock-surfaces of a light grey colour, there is what may appropriately be called a grim array of many hundreds of huge and black Silurian grit and slate boulders, which are apt to suggest the idea that they are about to spring into life! I think it must be obvious to any one who has made the pedestals of boulders a special study, that many, if not most of these boulders, have found resting places on pre-existing fragmentary projections of limestone rock, after the manner of the perched blocks, which may be seen in all countries which have undergone extensive glaciation, and I have little doubt that had Mr. Tiddeman's attention* been particularly directed to the subject, he would have agreed with me that the formation of the pedestals must have partly, if not chiefly, taken place before the boulders were left on them by the melting of the ice which transported them. But Mr. Tiddeman's object was the more important one of discovering glacial striæ on the pedestals under the boulders, where they had been protected by the boulders from the action of rain.

VII. *Evidences of the pre-existence of many of the Pedestals.*—That many of the pedestals must have existed before the arrival of the boulders would appear from the following facts:—1. Many of the boulders have no pedestals, and many have pedestals which do not fit the boulders; in other words, a pedestal may look narrower than a boulder when viewed endwise, but wider than a boulder when viewed sidewise; many

* See Quarterly Journal Geological Society, Vol. xxviii.

boulders resting on flat surfaces may be seen projecting over miniature cliffs, and many have two or more pedestals with vacant spaces between them, which could not have been excavated after the arrival of the boulders, because the latter would have protected the underlying rock-surfaces from the action of rain. In the case of the Norber Boulders, which rest on divided pedestals with one or more vacant spaces under which preserved glacial striæ may be seen on looking in from without, it is clear that the vacant spaces could not have been excavated by lateral pluvial action after the arrival of the boulders, because the pluvial or any other kind of aqueous action would have obliterated the striæ.

VIII. *Pedestals formed since the arrival of the Boulders.*—These pedestals vary from almost nothing to about seven inches in height. Those of them which, from their shape, would appear to have been left by the splashing down of rain-water from the boulders, may average about six inches in height, or nearly the same as the pedestals on the Eglwyseg plateau near Llangollen. I do not remember having seen Boulder-clay on the surface of the flat limestone rocks of the Norber plateau, though the spaces between many of the blocks in situ are often partly filled with a kind of grass-covered earth, which may have resulted from the accumulation of the insoluble part of the limestone. On the supposition that the boulders were transported by a great sheet of land ice (as Mr. Tiddeman believes), little or no Boulder-clay would be allowed to gather, according to Professor Geikie ("Pre-historic Europe," p. 289). Had the sea, with boulder-laden floating ice, swept over the high rocky plateau, there would have been still less likelihood of Boulder-clay being deposited.

IX. *Pedestals of Boulders in Ireland.*—My attention has lately been directed to a work entitled "Fissures, Fractures, and Faults," by Mr. Kinahan (of the Irish Geological Survey), in which he states that on the Arran Islands, where the rain-fall is great, the limestone has weathered away from four to six inches since the glacial period, as proved by the unweathered pedestals of limestone under the erratic blocks; while inland similar pedestals are seldom three inches in height.

X. *Bearing of the above Facts on the Time which has elapsed since the Close of the Glacial Period.*—After making a series of calculations based on the results of observations made in the two districts described in this paper, I was led to the conclusion (as already hinted) that the *average* depth of the hollows which have been excavated around boulders by the pluvio-torrential or mechanical action of rain-water (assisted by its chemical action under favourable conditions) is *not more* than about *six inches*. With regard to the rate of denudation, the extension of many flat rock-surfaces under boulders (especially on Norber plateau) shews that it must be exceedingly slow. But if we allow a thousand years for the excavation of only an inch in depth of the hollows around the boulders, this would give us not more than 6,000 years as the time which has elapsed since the boulders were left in their present positions through the melting of the ice by which they were transported. These calculations are only vaguely appproximate, but I think they are sufficient to shew that many geologists have shown a tendency to exaggerate the time which has elapsed since the close of the glacial period.

XI. *Perennial Snow or Ice on High Plateaux during Neolithic times.*—Professor Geikie, as already stated, is of opinion that the second great glacial period was

divided into two by a mild interval. But though this may have been the case in Scotland, or farther north, it may not have been so (at least to the same extent) in England and Wales; and I think we are therefore at liberty to believe that on the *high plateaux* in the north of Wales and England, which form the main subject of this paper, ice, or ice alternating with snow, may have been perennial, though it may have been different in the lowlands and farther south. If so, ice or snow on the Eglwyseg and Norber plateaux, which rise to between 1,000 and 1,300 feet above the sea-level, may have lingered until about 6,000 years ago, so as to protect the supports of boulders from the action of rain.

XII. *Close of the Glacial Period in North America.*—It is well known that many American geologists (including several who have been honoured by the Council of the Geological Society of London) are convinced that the glacial period in the Niagara and Michigan district, terminated as late as about 6,000 years ago. From recent reports it would appear that the Niagara Falls have lately been receding at the rate of about 10 feet in 24 years, or about 2½ feet in a year; and this accords with the results of observations made by the late Mr. Belt and Mr. James Hall, who found that the falls had receded in solid rock about three miles since the Niagara channel had been partly filled up with glacial drift. Dr. Andrews has made a series of very precise observations on the raised beaches of Lake Michigan, which shew that the surrounding country rose out of the glacial sea between 5,500 and 7,500 years ago. Many rivers besides Niagara have made new channels in the glacial drift by which their old channels were choked up.

XIII. *Astronomical Proofs of the Recent Close of the Glacial Period.*—According to Lieut.-Colonel Drayson, in

the Quart. Journ. Geol. Soc. for 1871, it would appear that 13,000 years before Christ the Arctic circle came down to latitude 54° 35′ N., or to about the latitude of St. Bees and Whitby. The climate commencing about 21,000 years ago would become more and more extreme up to about 15,000 years ago, and then gradually more and more equable to about 6,000 years ago.

XIV. *Historical Objection to the Recent Close of the Glacial Period.*—Some notice ought to be taken of an objection to the recent termination of the glacial period made by Professor Bonney, on the ground that if it came to a close so late as 6,000 years ago, the climate would have continued down to 3,000 years ago sufficiently cold to excite the notice of historians. But, according to Colonel Drayson's calculations, the climate would have lost its extreme character much earlier than 3,000 years ago. It may, likewise, be remarked, that glacial conditions in Britain never extended farther south than the Bristol Channel and Thames Estuary, so that in countries farther south the climate, 3,000 years ago, may not have been sufficiently extreme to invest it with historical interest.

XV. *Bearing of the Subject on Sacred History.*—Were a period of more than 6,000 years to be assigned as the time which has elapsed since the glacial period, there would be nothing inconsistent with the statements contained in the first chapter of Genesis, as the words, "In the beginning" imply no particular date. It does not seem to be generally known that the marginal figures 4004 B.C. were placed against the first verse of Genesis by Bishop Lloyd, of Worcester, so late as the year 1701; and that in Dr. Hales' new Analysis of Chronology, as many as one hundred and twenty different opinions are given concerning the date of the creation.

Such being the case, it would appear that geologists are at perfect liberty to pursue the study of their science without any fear of coming into collision with sacred history.

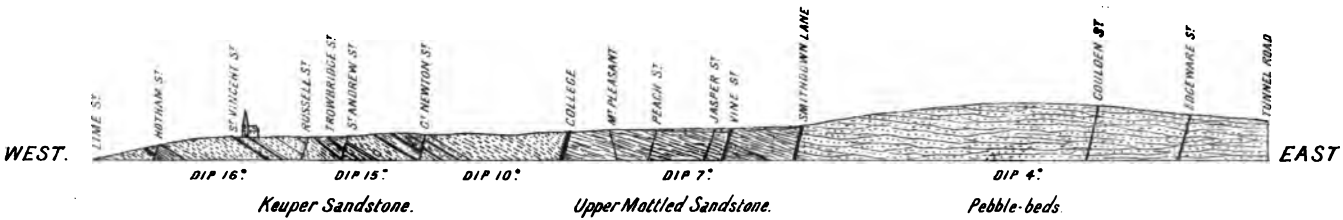
There would appear to be no evidence from which the date of the glacial submergence can be even approximately ascertained, especially as it was followed by a period of land-ice; but there is a remarkable loamy deposit called Loess, which is generally without sea-shells, and which, in China, with a thickness of 1,000 feet, ascends to an elevation of not less than 3,000 feet. Mr. Howorth, of Eccles, Lancashire, who has devoted much attention to this deposit, believes that it was accumulated by a great post-glacial fresh-water flood. On many points I fully agree with him, but the subject requires to be more fully investigated.

SECTION ACROSS THE TRIAS RECENTLY EXPOSED BY A RAILWAY EXCAVATION IN LIVERPOOL.

By G. H. Morton, F.G.S.

During the last eight years a very important section of the Triassic Strata has been exposed in Liverpool, by excavations for widening the line of the London and North-Western Railway Co. The section presents a solid wall of sandstone on both sides of the new Railway cutting from Lime-street Station to Edge Hill Station, a distance of 2,300 yards from east to west. The height of the rock on each side varies, but is usually from 50 to 80 feet above the railway. The section is represented by this diagram, which is on the horizontal scale of 40

SECTION FROM LIME STREET STATION TO EDGE HILL STATION.



feet to the inch, and on the vertical scale of 10 feet to the inch. The base line of the section is the level of Lime-street, while the middle line represents the railway gradually ascending to the east. I am indebted to Mr. Henry A. Dibbin, C.E., the Engineer of the Company, and to Messrs. Nichols and Keyte, for affording me every facility for examining the strata, which I have constantly done during the period the work has been in progress.

Before describing the strata exposed in the section, it is advisable to briefly refer to the Geological formations that occur in the country around Liverpool. A large portion of the City is situated on the Keuper, and the remainder on the Bunter formation; or according to an older nomenclature, it is on the New Red Sandstone. The subdivisions of these formations were first represented on the Geological Survey Map of the district by Prof. Edward Hull, F.G.S., in 1854, and they were afterwards described by myself in 1856. These subdivisions are the

$$\text{Keuper}\begin{cases}\text{Red Marl.}\\\text{Keuper Sandstone.}\end{cases}$$

$$\text{Bunter}\begin{cases}\text{Upper Mottled Sandstone.}\\\text{Pebble-beds.}\\\text{Lower Mottled Sandstone.}\end{cases}$$

During the last twenty years all these subdivisions have been found to be much thicker than formerly supposed, while several recent shafts and borings tend to prove that the Lower Mottled Sandstone is a series of sandstones and marls which may be of Permian age. This subdivision, however, does not occur near the section under description, except at a great depth.

RED MARL.

The *Red Marl* consists of red and grey shale with interstratified seams of clay of the same colour. On the east of St. James' Cemetery it is 100 feet thick, but in Wirral it was proved to be 320 feet when boring through it in search of coal in 1861.

KEUPER SANDSTONE.

The *Keuper Sandstone* consists of white, yellow, and red sandstone, with bands of red and grey shale and clay; the sandstone at the base being a conglomerate or breccia. Under Liverpool the Keuper Sandstone is 400 feet, but at Storeton, in Cheshire, it is only 208 feet thick, for the upper beds have been denuded.

UPPER MOTTLED SANDSTONE.

The *Upper Mottled Sandstone* consists of soft red, or yellow sandstone with grey streaks, seldom, if ever, fit for building purposes, and probably graduates downwards into the Pebble-beds beneath. It was formerly considered to be 400 feet in thickness, but in a boring for water at Flaybrick Hill it seemed to be 550 feet.

PEBBLE-BEDS.

The *Pebble-beds* form the thickest and most important subdivision about Liverpool, being extensively used as a building stone. The upper beds, about 400 feet thick, are of reddish-brown sandstone, with very few, if any, pebbles. The lower beds, about 600 feet thick, are of sandstone of the same reddish-brown colour, but contain numerous quartz and quartzite pebbles, and separated by frequent bands of red and grey shale. The thickness of the whole of the Pebble-beds proved in the Bootle bore-hole, when sinking for water, was about 1,000 feet, but probably the subdivision becomes thinner to the eastward.

DESCRIPTION OF THE SECTION.

On the Geological Survey Map, Sheet 79, N.E., the ground crossed by the line of section is represented as Pebble-beds on the east and Keuper Sandstone on the west, with a fault between, along the line of Bedford-street. When the soft sandstone, which occupies an intermediate position, was first noticed in 1862, I was of opinion that the base of the Pebble-beds occurred at the bottom of Edge Hill, and that the *Lower* Mottled Sandstone cropped out from underneath. The section, however, shows that this soft sandstone belongs to the *Upper* Mottled Sandstone, which has been thrown down to the west by a fault, and that there are many other faults running north and south, all tending to bring in higher strata in the same direction. It also shows the exact position of the fault between the Bunter and Keuper formations, which was not known before.

If the section had been drawn on the same scale, horizontally and vertically, it would have been four times as long as it is, but having been so much contracted, it has been necessary to represent the dip of the strata as much greater than it really is, and the hade of the faults is reduced for the same reason. The actual dip of the Pebble-beds in the Railway cutting is 4° east, the Upper Mottled Sandstone 7°, and the Keuper Sandstone 15°, dips exaggerated on the diagramatic section, so as to cause the beds of shale to appear in their proper positions with regard to outcrop and faults.

The *Pebble-beds* crop out for 914 yards along the east of the cutting, and are represented by a solid wall of hard, fine grained reddish brown sandstone, with thin bands of a grey colour. There are no shale-partings, and not a single pebble of any kind has been noticed. The sand-

stone is an excellent building stone, and very large blocks are obtained, as there are very few joints. Only two faults occur along the great length of the Pebble-beds exposed, and they are of very little importance.

One of these faults is under Edgeware-street, 25 feet east of the bridge, with a downthrow of 3 feet to the west, and the other under Goulden-street, with a similar downthrow of 4 feet 6 inches. The thickness of the sandstone exposed is about 250 feet. It belongs to the top of the Pebble-beds, and is succeeded by the Upper Mottled Sandstone, a very short distance beyond the east end of the cutting where covered with the Boulder clay. The Pebble-beds end towards the west with a fault under that side of Smithdown Lane, being a downthrow of about 150 feet to the west, bringing in the overlying subdivision.

Upper Mottled Sandstone.—The Upper Mottled Sandstone is a fine grained, soft and bright red sandstone, with grey streaks. It readily crumbles into sand, and is never hard enough for building purposes. A little further west, close to Vine-street, the lowest visible (10 feet) of sandstone is harder, more like that of the Pebble-beds, so that it is probable that the base of the Upper Mottled Sandstone is exposed there; but under the west side of the street there is a fault which throws down the sandstone in the same direction, probably about 100 feet, for nothing is seen again of the underlying Pebble-beds. The Upper Mottled Sandstone then continues cropping out to the west without any change in lithological character. There is a fault on the west side of Jasper-street and another 22 yards west of Peach-street, but they are evidently very small downthrows to the west. On the east side of Mount Pleasant there is another small fault, which throws the sandstone

up on the west, but only to the extent of 6 feet, and of no importance. A little further the great fault which brings in the Keuper Sandstone occurs, with a down-throw of about 600 feet to the west. It was well exposed a few months ago, and is still visible in a short tunnel under Mount Pleasant and Brownlow Hill, and it runs under University College, which is situated partly on the Upper Mottled Sandstone and partly on the Keuper Sandstone.

Keuper Sandstone.—The highest strata of the Keuper Sandstone occur on the west of the boundary fault, and the position of the Red Marl, had it occurred, would have been just over the yellow sandstone at the top of Brownlow Hill. About 500 yards to the south of the line of section the same yellow sandstone occurs in St. James' Cemetery, with 100 feet of the Red Marl over it, both subdivisions being exposed for some distance. On the south-west of University College, a large quarry was discovered filled with *débris*, and it is shown on an old Map of Liverpool by Charles Eyes, dated 1785, as "Brook and Seacomb's Quarry." The upper part of the sandstone is yellow, but lower down it changes into red. Below about 150 feet of the yellow and red sandstone, several thin beds of shale crop up and end against a fault on the west of Great Newton-street, which throws down the strata about 30 feet, and several beds of shale then rise to the surface. These beds are subject to rapid changes in thickness and lithological character, and often alter considerably, or thin away altogether within the space of 50 yards. The thickness of those under Gill-street varies from 3 inches to 6 feet, and are usually of a deep red colour, though sometimes yellow or grey. They are associated with a conglomerate, 20 feet thick, which contains numerous nodules, or rounded

masses of clay and a few quartz pebbles, and resembles the base of the Keuper. Another fault occurs between St. Andrew-street and Trowbridge-street, and throws down the strata again to the west about 80 feet, bringing in two of the upper beds of shale, which rise to the surface at Jervis-street and on the east of Russell-street. Under the yards, at the back of the houses, on the west of Russell-street, there is another fault with a downthrow of about 50 feet to the west, and the beds of shale are brought in again. The lowest bed is 3 feet thick under St. Vincent-street, but thins away downwards to a few inches at the bottom of the cutting about 100 feet distant.

The sandstone forming the base of the Keuper is 75 feet in thickness, and crops out from under the lowest bed of shale in Lime-street Station. It is a hard light yellow sandstone, with a few distant partings of shale from 1 to 3 inches thick. It contains numerous nodules of clay, but no quartz pebbles have been found, though they are frequent in the basement beds in several places on the opposite side of the Mersey.

Under the base of the Keuper a soft yellow sandstone crops out, and it is probably the top of the Upper Mottled Sandstone, but only 30 feet are exposed, for a few yards to the west there is another fault, which brings down some of the beds of shale again, so that there must be a downthrow of at least 90 feet. Beyond the western end of the section the shale beds crop out between St. George's Hall and the Free Public Library and Museum, while still further west the Upper Mottled Sandstone comes in, probably faulted and thrown *up* against the Keuper Sandstone, the whole of the latter being in a great trough fault.

The position of the Keuper, as a wedge-shaped mass

of sandstone, with the Bunter formation faulted against it on the east and west, is of great local interest, and it is easy to understand how the outcrop of the subdivisions under the city has not been satisfactorily explained before, in the absence of such a continuous section as that described.

The remarkable absence of faults in the Pebble-beds has an important bearing on the construction of the Mersey tunnel, which will have to be carried through those beds along its entire length. The section shows that while faults are numerous in the Keuper Sandstone, which was frequently fractured during subsidence into a depression, the Pebble-beds are very little faulted. A few days ago, when under the Mersey, I did not find a single fault, either in the tunnel or in the heading beneath, neither did I find a single pebble in the sandstone, which proves the strata to belong to the upper part of the Pebble-beds. There were a few thin bands of shale, with the exception of a single bed about a foot in thickness. Most of the rock in the tunnel was covered with brickwork, but in the level beneath it was left exposed.

EXPERIMENTS ON THE CIRCULATION OF WATER IN SANDSTONE.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

In 1874 a Committee of the British Association was appointed "for investigating the circulation of the underground waters in the New Red Sandstone and Permian Formations of England." This Committee has since issued annual reports containing a great deal of valuable, but undigested information, relating to the well sinking and borings in various places.

In 1877, being then on the Committee, I submitted a report to them, with sections, on the South Lancashire Wells, which is published in an Appendix to the General Report. It was an attempt to deal with the facts in a scientific way, so as to educe some principles which might serve to explain the mode in which water circulated through the New Red Sandstone rocks.

During the present year, while instituting some experiments on sandstones, my attention was accidentally recalled to the consideration of the circulation of water in sandstones. What I am about to describe to you are nothing more than laboratory experiments; but I venture to hope that they may be found of some service practically, as assisting to interpret what takes place in Nature on a larger scale.

The capacity of sandstones for absorbing water has been the subject of many experiments. Notably, in our own Society, Mr. Isaac Roberts, F.G.S., made such an investigation, which is described in our Proceedings for 1868–9; and a very full table by Mr. E. Wethered, F.G.S., on the Porosity and Density of Rocks, from experiments of his own, is in the British Association Report of 1882.*

My own experiments, which, though also dealing with the capacity of the New Red Sandstone for absorbing and retaining water, relate in their more original aspect to the mode in which capillarity manifests itself, and the way in which the water circulates in the stone.

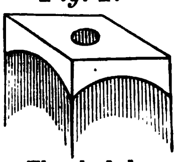
These experiments were made with dressed bars of Red Sandstone from the quarries for building-stone at Runcorn and at Everton; they were prepared for me

* These densities appear to me to be excessive, the particles of Millstone Grit being given as 3·01 in one case, and in another the Inferior Oolite at 3·8, pp. 236–7.

by Mr. Hugh Yates, to whom I must express my thanks. Superficially there is little to distinguish these stones from each other, though the former is in the Keuper, and the latter in the Pebble-beds of the Bunter. They are often used indiscriminately in the same building.

My first experiment was with Bar No. 8, Runcorn Stone, which I half-immersed in a can of water, end on. The measurement taken with very fine callipers was 14·92 by 1·92 by 1·92 inches = 53·38 cubic inches. The water rose by capillarity 5 inches the first hour, 1 inch more the next 25 minutes, ¾ inch the next 25 minutes, and finally appeared at the *top*, in the centre of the bar, in a total of 2¼ hours—see Fig. 1. Leaving it in another ¾ of an hour—3 hours in all—I weighed it, and found it had gained 4 oz. of water. I then placed it back in the water the other end up, and after leaving it soaking for some time, weighed it again, and found it was exactly the same weight as before. I then totally immersed it in the bath and left it to soak. It still weighed the same. This showed that its capacity for water had been fully satisfied by capillarity alone.

Fig. 1.



The shaded part represents the wet part of the stone.

1 oz. of water at 62° Fahr. measures 1·73 cubic inches.

$$4 \text{ oz.} \times 1{\cdot}73 = 6{\cdot}92.$$
$$53{\cdot}38 - 6{\cdot}92 = 46{\cdot}46.$$

Therefore, 53·38 cubic inches of Runcorn Stone contains 46·46 cubic inches of solid material, and 6·92 cubic inches of interstitial space between the grains which can be filled with water by capillary attraction.

The weight of the stone dry was 64·7 ounces — $\frac{46{\cdot}46}{64{\cdot}7} = 0{\cdot}718$. One ounce of solid material $= 0{\cdot}718$ cubic inch, and the specific gravity was there-

fore 2·4. Thus it is highly probable that there are some interstitial spaces in which the water does not displace the air, as I find the specific gravity of the siliceous sand of our sandhills to be 2·62.

The quantity of water absorbed was equal to 3·24 quarts per cubic foot of sandstone.

I have given this experiment in detail to show my method of working.

Experiment No. 2.—This was with a bar of Everton stone 14·88 by 1·88 by 1·88 = 52·58 cubic inches, weight dry, 4 lbs.

I immersed it 8½ inches, end on, in water. The first hour, the water rose one inch; in three hours, 1¾ inches; in 13½ hours it had only risen a total height of 4½ inches. In 28¾ hours the damp appeared, as before, as a spot in the middle of the top of the stone. The water rose in the stone, as in the previous experiment, like the mercury in a rising barometer, convex at the top. The surafce of the rising water would really be represented by a dome cut to fit a square plan. I left the stone standing in the water another 8½ hours, and then weighed it. It had taken up 3⅝ ounces of water. I put it back in the water the other end up, and weighed it again in another 24 hours. It had gained in all 3¾ ounces of water. I then totally immersed it in water, and let it soak, but it gained no more water.

Calculating as before—the water absorbed is equal to 3·08 quarts per cubic foot, and the specific gravity of the stony material 2·4, as in the former case.

Drying.—The experiments not being simultaneously made, I can institute no exact comparison between the stones in their relative times of drying, as they no doubt were subject to some varying conditions of temperature and dryness of the air. No. 1, exposed all round to the

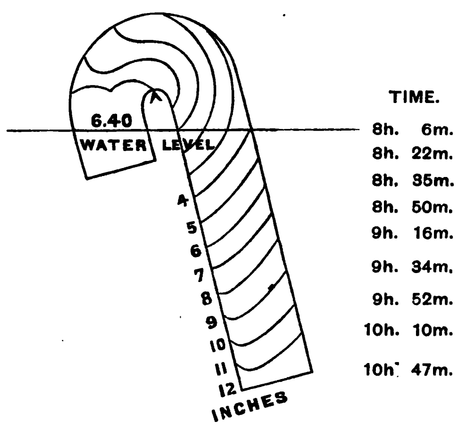
air at an average temperature of about 62°, lost two ounces of water in 24 hours. In 48 hours in all, it still retained three-quarters of an ounce of water, but had regained its natural colour. In 96 hours it still held a quarter-ounce, and in 100 hours it was practically dry. No. 2, after 48 hours exposure, held half-an-ounce of water. So that although No. 2 took up the water so much more slowly, it parted with it at the same rate, roughly speaking.

Stone Syphon.—It next occurred to me that it would be possible to syphon out the water from one vessel to another at a lower level, by means of, or through solid stone. I therefore had a stone (Runcorn) made in the form of a plumber's bend. It was 3 inches by 3 inches in section, 15 inches long from the top of the bend to the termination of the longer leg and 6 inches to that of the shorter. The stone was wet when I first got it, having only just been worked. In that state I fixed it with the short leg in a vessel of water and the long one in a dry dish. The head of water was 8½ inches. The water gradually accumulated at the termination of the long leg and stood on the surface in small beads. In one hour the first drop of water detached itself from the the stone. On measuring the water after the expiration of 21 hours 58 minutes, I found it had run out 29·45 cubic inches of water, or at the rate of 1·36 cubic inches per hour, the difference of level of the water in the top and bottom vessels being 7½ inches. On another occasion it ran at the rate of 1·57 cubic inches per hour; on another, 11 hours at the rate of 1·44 cubic inches per hour. The water delivered was in all cases accurately measured with a rain-gauge measurer. The difference of speed in the circulation of the water probably was to some extent affected by the varying head, but the experiments did not make this quite clear.

I then left the syphon to dry in the air, as I was curious to find out in what way the water circulated through it. When quite dry, I repeated the experiment. The water rises in the stone and progresses through it with a such a defined line that it is quite easy to see what is going on. In five minutes the water rose two inches on one side to the crown of the inner bend; on the other it did not rise so quickly, due, no doubt, to the bedding of the stone being more pronounced on one side than the other. I have marked at intervals, in the accompanying diagram, Fig. 2, the course of the water through the stone and the edge of the water as it turns the bend shews some very pretty curves.

Fig. 2.

Diagram of Stone Syphon, shewing progressive absorption of water.



For the last eight inches I took the time at each inch of progression, and found it averaged 18 minutes per

inch. The last four inches were very regular in the times, as will be seen on reference to the diagram. In 4 hours and 7 minutes it became fully saturated. It took up the water for the last four inches at the rate of 4·47 cubic inches per hour. In an experiment extending over 12 hours the syphon ran out 17·86 cubic inches, or 1·49 cubic inches per hour. Thus the syphon parts with its water at one-third the rate it progresses through the stone during the time the last four inches are being saturated. On weighing, the syphon was found to contain 14 ounces of water, or 24·22 cubic inches.

My next experiment was with the Runcorn Stone No. 8, already described, measuring 14·92 by 1·92 by 1·92, and another Runcorn Stone, 15·03 by 5·5 by 5·5 inches; the total cubic capacity being 508 inches. These two stones were placed end on in a measured quantity of water. When saturated, I found they had taken up, together with water lost in evaporation, 71·36 cubic inches, or 1·03 quarts. If we allow 3 oz. as lost in evaporation, the proportion of water the two stones hold is almost exactly the same as No. 8 alone. As one experiment was by weight and the other by direct measurement, this is a very satisfactory proof of accuracy.

I found, however, that the larger stone, although its bedding was horizontal in the experiment, absorbed the water proportionately more rapidly than the smaller. When the water was 12¾ inches high in the large stone, it was only 10½ in the smaller. The water, as before, made its appearance in the centre of the top of the stones first. Drying them in the air, standing on end, the water retreats in the stone exactly in the same way that it rises.

Experiments with Sand.—I now thought I should like to see how loose sand acts under similar circumstances. I therefore filled a glass tube, $\frac{5}{8}$ inch diameter, with dry sand from the sandhills, through a funnel, while standing it vertically in sand at the bottom of a tumbler. I then poured water into the tumbler—the water rises up the first inch of the tube with astonishing rapidity, gradually decreasing in speed. Though I left it more than a week, the water only rose $3\frac{1}{2}$ inches and there remained. In filling it again with dry sand as before, and *tapping the tube,* the water rose the same evening above $3\frac{1}{2}$ inches. I then filled a tube, $1\frac{3}{4}$ inches diameter, with similar dry sand, shaking it well down. The water in this case rose $7\frac{1}{4}$ inches in the tube, at which level it remained. A careful experiment made with a gauge glass showed that 9 oz. of sand absorbed $2\frac{1}{4}$ oz. of water. The 9 oz. of sand measured 9·81 cubic inches, and the $2\frac{1}{4}$ oz. of water 3·89 cubic inches. Therefore, $9{\cdot}81 - 3{\cdot}89 = 5{\cdot}92$ cubic inches of solid sand matter. The specific gravity of the sand being thus 2·62.

I have elsewhere stated in round figures,* that 12 cubic feet of this sand will absorb five cubic feet of water. This more accurate measurement makes the water absorbed $\frac{1}{20}$ less; but 5 of water to 12 of sand is near enough for practical purposes.

I made other experiments, but it would be mere weariness to detail them here. So let us see if we can extract anything of practical moment from those already described.

As regards Wells and Water Supply.—My experiments do not shew the vertical height that water will rise to in the stone by capillarity. One of the bars of Runcorn

* Geological Magazine, January, 1884.—"Miniature Domes in Sand."

stone, 15 inches long, standing in half-an-inch of water, became saturated to the top in 24 hours. A similar bar of Everton stone absorbed water up to 8¼ inches in the same time, and in five days it had risen to 12½ inches. It is, however, pretty evident that when this limit of capillarity has been reached, the addition of any water to the height of the column would make it run through the stone. Thus we can understand that rainfall, soaking into the ground as moisture only, may, when the point of saturation of the underlying rock has been reached, create a circulation of water in the rock. Before my experiments were made, this point in the theory of the circulation of underground water was anything but clear to me. This view of the matter also enables us to understand how the rock may be supplied with water, even under the very general mantle of Low-level Boulder-clay which covers the valley of the Mersey.* It will absorb moisture from anything merely damp, and the water collecting in a vertical column or accumulating vertically in the rock, is ready to flow when tapped at a low level. Nature provides cracks and fissures which ramify through the sandstone rock; and through these fissures and the planes of bedding, or at the junction of intercalated beds of marl, the water flows by gravitation to the nearest river channel.

When a well is sunk, the conditions of drainage are altered. If kept pumped down, the lowest level to which the surrounding water can drain, is the *locus* of the well. A portion of this water therefore is intercepted and diverted from the natural channels. I have

* Mr. Wm. Whitaker, F.G.S., in his able Presidential Address to the Norwich Geological Society (Geol. Mag., Jan. 1884, pp. 23–29) classes some of the Boulder-clays as impervious; my own view is that all are, through capillarity, in different degrees, pervious.

elsewhere shewn * that a large extent of ramifying fissures in connection with a well are a necessity for its success. The area of the rock affected by the pumping is proportional to the extent of these fissures, for otherwise the well would not be able to draw its supplies from any great distance.

The experiment with the syphon also clearly shews that a very great deal of water may be drawn laterally from rivers flowing over sandstone, and bringing water from other sources, which may serve to explain the prodigious quantity of water which can be and is, drawn artificially from the Red Sandstone. In the upper part of these river valleys a great deal of drift has been removed, or there are gravels lying upon the rock, saturated with water. It also seems to explain a much debated point—the increase of chloride of sodium in some much pumped wells near the river Mersey; for the pressure of the column of fresh water being relieved, the sea water may begin to interchange by endosmosis with the water in the rock. The experiments also explain why, by pumping down a well to a constantly low level, a larger supply of water is obtained, because the hydraulic head acts from a longer distance and a consequently larger area. Taking the water filtered through the stone of the syphon, which had an area of 9 superficial inches, at only 1 cubic inch per hour (instead of 1·49, the rate at which it actually delivered), this would equal 2 cubic feet per yard, or 9,680 cubic feet of water per acre per 24 hours, or 6,195,200 cubic feet per mile. It is thus seen that with a good system of fissures in connection with a well what a vast quantity of water may be

* British Association Report, 1877.—"On the South Lancashire Wells," pp. 66-72.

drawn through the rocks. The theory that looks upon the Red Sandstone as simply a storehouse of water that we are gradually exhausting, is on the face of it fallacious.

It is well known, however, that these fissures are surface phenomena, which are reduced and probably finally disappear with depth. Joints are by some considered to be so too. The fissures are either fractures or enlarged joints. Movement of the rocks may have in the first place fissured them, and undoubtedly the circulation of the water that has been going through them for countless ages has enlarged them. This is not necessarily due to mechanical agencies alone; the chemical action of water will effect the same purpose. It is a well known fact that the water of wells in the New Red Sandstone increases in hardness with their age, and that when a new bore is put down the new water is usually softer than the old water. Sandstone soaked in water becomes soft, and if a constant circulation is kept up, it naturally follows that the softened cement of the particles becomes more easily dissolved and taken up by the water. The water also possesses more active chemical qualities for effecting this dissolution from its constant renewal from the surface.

Our Secretary, Mr. Morton, F.G.S., has pointed out that the Keuper Sandstone in the railway cutting between Lime Street and Edge Hill is much more shaken and faulted than the Pebble-beds. It is highly probable that the lower we go down into the earth's crust the fewer the small faultings, though the main faults must penetrate to a great depth; but these, as a rule, are closed up. It is only when within the influence of atmospheric agencies that the fissures are formed. I was lately much struck, in examining the Penmaenmawr Sett Quarries, to find the weathering of the rock to follow the joints to

the bottom of the quarry; and Mr. Charles Darbishire pointed out to me, at a great depth below the natural surface, a fissure or cave, into which a man could get. Particular bands of this rock also seem to have decayed to a great depth. This is, I believe, all the effect of atmospheric action by percolation of rain water. But for the rain water to circulate there must be some natural drainage to a lower level. Probably the cause of the failure of the deep Bootle well was because it penetrated homogenous sandstone possessing no ducts which could quickly convey the filterings of the rock to the site of the well.

As Regards Building Stones.—In pursuit of my profession I have of course used much of the stone experimented upon. I long ago found out that when used as factables to a roof, copings to a parapet wall, or indeed anywhere where the rain could come vertically upon it, that it was impossible to keep out the damp. Point the joints and paint the stone as you will, the wet still comes through. I therefore adopted the plan of bedding stone in these situations on sheet lead. This was the only effectual cure. I also found it absolutely necessary to have no through-stones; they infallibly conveyed the water through the wall to the plaster inside, and indicated their presence by square yards of damp. I therefore always arranged to have a brick-backing behind the stone-work. Wood beams or wood-work of any kind in contact with this stone-work infallibly rots. There are many appliances that profess to close the pores of the stone, but, hitherto, those I have used have not proved satisfactory. If each individual stone could be dipped in some solution, that would probably prove the most effectual cure. As it is, the solution is applied only on the face, when the work

is set, leaving the wet to penetrate at the joints. It is, however, I think, a pretty generally established fact that weathering tends to close the pores of the stone, and put what is called a "hard skin upon it;" but this takes time. Stone foundations will draw the moisture up from the earth and play havoc with a building. Brick, and almost any material will also do it, but to a lesser degree. The prevention is, however, simple and easy by building in what is called a damp-proof course, of pitch, or other non-absorbent material. The cure in an existing building is more difficult and expensive, for then the whole structure has to be "underpinned" to insert it. Old buildings, so far as my experience extends, never possess damp-proof courses.

A Red Sandstone house may be a very handsome building, but then it may be holding tons of water in its pores! A wall 60 feet by 30 feet and 2 feet thick is capable of holding some 6 tons of water, and such a wall, if exposed to the north-west, in an open country, in our neighbourhood, in a rainy winter, would, no doubt, get saturated. This means expending more fuel to convert part of this water into vapour! The difficulty is surmounted to a great extent by building hollow walls, the inner wall being of brick. Woe unto the man who has not taken this precaution!

It would certainly appear, from the experiments detailed, that the compact stone of the Pebble-beds is the better building stone, though the Runcorn stone (Keuper) can be obtained in larger and more homogenous blocks. The Everton stone absorbed the water much more slowly, and parted with it as quickly. I have no doubt, also, that, other things being equal, it will last longer; though this quality seems to be getting day by day of less moment, the world moves so quickly, and one

building is so rapidly removed to make way for another. How different from the good old days, when families lived in the same house for generations! Nevertheless, I have always been an advocate for good building, and practised it, I hope, to the practical benefit of my clients.

Other applications of the principles disclosed will, no doubt, occur to you. It is not often that I have connected geology with any utilitarian object in the papers I have had the honor to read before you. At the same time, its use has been present to my mind, and I think what I have shewn you to-night may to some extent answer those troublesome people who are always asking *Cui bono?*

ON INDENTED PEBBLES IN THE BUNTER SANDSTONE, NEAR PRESCOT.

By Charles Ricketts, M.D., F.G.S.

I have received from Mr. James Coutts, of Glasgow, a rounded purple quartzite pebble obtained from the Old Red Sandstone of Aberfoyle, Perthshire; it was accompanied with a request that I would, if in my power, assist in determining the cause of the remarkable indentations, of which seven appear on its surface, and of the fractures associated with them. The specimen is similar in character, and from the same locality, as some described by Professor James Thomson, F.R.S., at the meeting of the British Association at Southampton.* Though, in order to cause the indents the pebbles must have been exposed to a crushing and grinding force against other hard substances, and the fissures are, apparently, dependent on the same cause, and

* Report; 1882, page 536.

though the sides of the fractures are re-cemented, there are no indications of its having been reduced to a semi-plastic condition.

Professor Thomson refers to only one author, the late Professor Page, who directed attention to similar examples; but there is added in the Report (page 537), by Mr. Topley, of H.M. Geological Survey, a list of twenty-three papers having reference to the subject, chiefly by English authors, but also by French and American. These references extend as far back as 1795, to the well-known author of a "Theory of the Earth," Dr. James Hutton. (Vol. I., page 467).

Several years ago I met with two or three examples of quartz pebbles in the Pebble bed Sandstone, near Prescot, which had slight marks or notches where two had come in contact. During a recent visit to the large quarry in Holt Lane, opposite the Prescot Workhouse, I was unsuccessful in obtaining any from similar beds of sandstone, which are extensively worked there; the contained pebbles are scattered, so that very few could be found near each other or in contact; even of these it was hardly possible to separate them from the matrix in consequence of its hardness. Near the entrance to the quarry, lying on the upper beds of this hard sandstone, there is a small patch consisting of a conglomerate, it may even now be called a gravel bed, of rounded quartzite pebbles embedded in an unconsolidated sandy matrix. Where it has been cut through in obtaining access to the quarry, the thickness is two and a-half feet, but it thins out entirely towards the south at a distance of twenty feet. It, as well as the hard sandstone where uncovered, is overlaid by thin bedded sandstone, which separates in slabs. Wherever these pebbles are in contact an indent is made to a greater or less extent in the

hard quartzite, forming smooth and regular hollows, similar to those in the specimen from Aberfoyle; and like it some bear many of these marks. Sometimes the sand (or it may be the substance removed by the grinding action) is compressed and consolidated round the hollows. Some of the pebbles are split in such a manner as to render it probable that the fracture has been due to the same compressing force that caused the indentations; in others the fractures must evidently be referred to other causes, for there is no relation between them and the indents; in several the process is still incomplete, and the fissures, from the appearance of their margins, indicate that they were in progress at a time previous to their deposition.

Sir A. C. Ramsay has given what appears to be the correct explanation of these indentations in Triassic and other pebbles. He states that "these stones are all beautifully rounded; and where they touch in the rock they are not scratched, but indent each other at the points of contact; the indentations being due to the fact that, while these gravels were still incoherent, newer strata were piled upon them, and the vertical pressure, consequent on this vast superincumbent pile, induced a lateral pressure in the loose-lying pebbles of the conglomerate; so that, being squeezed not only downwards but outwards, they ground on each other, and, partly by the aid of intervening grains of sand, circular indentations were formed, sometimes an inch in diameter." * It has occurred to me that the grinding movement required to produce the depressions might, to some extent, be increased by the removal of support when the water was drained from the rock-strata by elevation above the sea-level.

* Quarterly Journal Geological Society, vol. xi., page 200.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

A. C. RAMSAY, F.R.S., F.G.S., London.
JOHN MORRIS, F.G.S., London.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
WILLIAM BRYHAM, Wigan.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
W. KING, D.Sc., Queen's College, Galway.
JOHN W. JUDD, F.R.S., F.G.S., London.
ARCHIBALD GEIKIE, D.Sc., F.R.S.

MEMBERS.

*ARCHER, F., B.A., Boundary Cottage, Crosby.
14, Cook Street.
*†BEASLEY, H. C., Prince Alfred Road, Wavertree.
*BOSTOCK, R., 8, Grange Lane, Birkenhead.
*BROWN, J. CAMPBELL, D.Sc., F.C.S., 27, Abercromby Square.
DAVIES, C., 8, Kinglake Street, Edge Hill.
DODD, J., 2, Derby Terrace, Rock Ferry.
*†ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackin's Hey.
FITZPATRICK, M., 62, Seel Street.

FITZPATRICK, J. J., 62, Seel Street.
†FOSTER, E., 7, Newstead Road, Smithdown Road.
GREEN, A., York House, Old Chester Road, Rock Ferry.
9, Canning Place.
GRIFFITHS, J., 4, Exton Park, Chester.
*HALL, H. F., F.G.S., Green Heys, Grove Road, Wallasey.
17, Dale Street.
HANCE, E. W., LL.B. (Hon. Treasurer), Municipal Offices, Dale Street.
HATHAWAY, T., C.E., The Mount, Bangor, North Wales.
HERDMAN, W. A., Prof., D.Sc., F.L.S., F.R.S.E., University College.
*HIGGINS, H. H., Rev., M.A., Rainhill.
HEWITT, W., B.Sc., 21, Verulam Street, Upper Parliament Street.
JACKSON, G. O., 15, Trafalgar Road, Birkdale, Southport.
JEFFS, O. W., 8, Queen's Road, Rock Ferry.
JOHNSON, J. H., F.G.S., 64, Albert Road, Southport.
JONES, T., Top Lane, Wallasey.
Orange Court, Castle Street.
LEA, T., Vale Cottage, Huyton Quarry.
*MACKINTOSH, D., F.G S., 32, Glover St., Borough Road, Birkenhead.
*McCLAY, J. L., Rose Villa, Victoria Road, Oxton.
*MARRAT, F. P., 21, Kinglake Street.
MANSELL, Rev. J., 10, Kremlin Drive, Stoneycroft.
*MOORE, T. J., C.M.Z.S.L., Newsham Drive, Newsham Park.
Liverpool Museum.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I., (Hon. Secretary), 4, Onslow Rd., Elm Park. 122, London Road.
McMILLAN, A., Conway, North Wales.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PARKINSON, J. C., 3, Alexandra Road, Waterloo.
PEARSE, W., 21, Harrington Street.
Green Bank Farm, Wavertree.
*†PICTON, Sir J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
PEARSON, J. E., C.E., F.G.S., Golborne Park, near Newton-le-Willows.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
*†RICKETTS, C., M.D., F.G.S., 22, Argyle Street, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., Valley Lodge, Borough Road, Birkenhead.